QUESTIONS AND PROBLEMS IN CHEMISTRY

DARROW

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QUESTIONS AND PROBLEMS IN CHEMISTRY

BY

FLOYD L. DARROW

HEAD OF SCIENCE DEPARTMENT, POLYTECHNIC PREPARATORY COUNTRY DAY SCHOOL, BROOKLYN, NEW YORK

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PREFACE

This little book is a systematic and logical development of the subject of Elementary Chemistry by questions and problems. The book is not intended for the use of the teacher, but primarily for the use of the student, as a guide to the everyday preparation of his lessons. In the teaching of chemistry I have found it exceedingly difficult to get pupils to come to class with any adequate preparation of the work assigned. In very many cases this has not been due to lack of study, and frequently more time is spent upon the lesson than should be necessary. The trouble lies in the fact that students are unable to analyze a lesson and determine what are the important points. Consequently they study all parts with equal intensity and none thoroughly. As a means of overcoming this difficulty I adopted the plan of mimeographing questions upon the lesson assigned and giving each pupil a copy. This gave him something definite to study, and he knew for himself when he had his lesson. The class liked the method. The recitations were very much improved. Time was economized and the results at the end of the year were most satisfactory. Finding the mimeographing of these questions each day a time-taking task, I privately published them in book form under the title of "A System of Questions and Problems in Chemistry." As such the little book proved helpful to so many teachers that the author feels justified in offering it for publication under circumstances that will insure a still larger field of usefulness. "Questions and Problems," while following the same plan as the original set of questions, has been brought thoroughly down-to-date.

Industrial processes and commercial applications have been especially emphasized, and yet the theoretical considerations of the subject have not been neglected. The tremendous influence of the war upon chemistry has been brought out in many suggestive questions. Teachers will find the inclusion of the questions of the College Entrance Examination Board and of the Regents of the State of New York for the last five years of great value in review work. The tables placed at the end of the book will make unnecessary any other reference for the constants needed in solving problems.

These questions can be adapted for use with any text. They will solve the problem of inadequate daily preparation, not only for secondary schools, but will be found quite comprehensive enough to meet the requirements of the freshman course in college. Their systematic use throughout the year should bring success in College Board and Regents examinations.

FLOYD L. DARROW.

BROOKLYN, N. Y.,
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QUESTIONS AND PROBLEMS IN CHEMISTRY

INTRODUCTION

1. Define physical change.
2. Define chemical change.
3. What is the essential difference between the two kinds of changes?
4. Name two examples of each kind of change and show why each belongs to the class designated.
5. Classify as chemical or physical the following changes:
   Freezing of water.
   Souring of milk.
   Burning of coal.
   Magnetization of iron.
   Solution of salt in water.
   Decay of wood.
   Liquefaction of air.
   Rusting of iron.
   Evaporation of a solution of salt and water.
   Refining of crude petroleum.
   Solution of a metal in an acid.
   Fermentation of sugar to alcohol.
6. Ice melts upon the application of heat, while wood chars. Explain why one of these changes is regarded as chemical and one as physical.
7. In what fundamental respect, then, do the products of chemical changes differ from the substances started with?
8. What are the three physical states of matter?

9. How may we change a substance from one physical state to another? Upon what two factors do these changes principally depend? Are they chemical or physical changes? Why? Illustrate by showing the changes of physical state to which water may be subjected. Could mercury, sulphur, and iron be subjected to these same changes?
10. How is a substance recognized? After a given change in some substance how are we able to determine whether or not the substance has undergone a change in composition?
11. Define the term property. What are the two classes of properties? Name five physical properties? How are such properties discovered?
12. In what way are the chemical properties of a substance discovered? Name several chemical properties.
13. Define matter, energy, substance.
14. Give examples of four different forms of energy and show that each answers to the definition of energy.
15. When a body parts with its energy what becomes of it? Is any of it lost? Is all of it transformed into useful work? When energy appears in some new form, what is its source? Is it newly created?
16. Show how the energy of the sun as a source may be made to *a*) turn a waterwheel, *b*) generate electricity, *c*) produce artificial heat and light, *d*) run machinery and trains, and *e*) effect chemical changes.
17. State the law of the conservation of energy.
18. How does the total weight of the products of the combustion of a burning candle compare with the total weight of the materials taking part in the combustion? Name and state the law which this illustrates. Give two other examples.
19. From the standpoint of chemistry, under what three heads may all the different varieties of matter be classified?
20. Make a list of ten common substances—gaseous, liquid and solid—and classify them as above.

21. Using common salt and iron filings as an example show how a mechanical mixture may be prepared. What sort of a change have the ingredients undergone? How do the properties of each ingredient now compare with its original properties? How may this be shown? Describe the separation of the ingredients from each other. What means are employed? In any part of the operation has there been a chemical change?
22. Define mechanical mixture.
23. Show how sulfur and iron filings may be made into a mechanical mixture and how this may be proved to be a mechanical mixture.
24. Now show how the above mixture may be changed into a chemical compound. How can you prove that it is no longer a mixture? By what chemical means can you show that it is now a chemical compound?
25. Define chemical compound. Illustrate your definition by showing how it applies to *a*) water, *b*) mercuric oxide.
26. Classify as mechanical mixtures or chemical compounds:

    A solution of salt and water.
    Air.
    Iron ore.
    Sugar.
    Alcohol and water.
    Crude petroleum.
    Copper oxide.
    Sea sand.
    Lime.
    Concrete.
    Glass.
    Milk.
27. Define element. In what way have the facts of radioactivity modified our former idea of an element?
28. What is the approximate number of elements? Name a dozen common elements.

29. What are the physical states of the elements? Name two belonging to each physical state.
30. What is meant by the occurrence of an element in *a)* the free state? *b)* the combined state? Give two examples of each.
31. Give two examples showing how elements may be united to form compounds.
32. What considerations have been instrumental in giving names to the elements?
33. What is a chemical symbol? How are the symbols of the elements obtained?
34. What is meant by chemical affinity?
35. Give examples of physical and chemical changes produced through the agency of *a*) heat, *b*) light, *c*) electricity.
36. What was alchemy and what did it contribute to the science of modern chemistry?

OXYGEN

37. To what class of matter does oxygen belong?
38. What three names are associated with the discovery of oxygen and in what ways? From what substance was it first obtained?
39. Where does oxygen occur in *a)* the free state? *b)* the combined state? Give reasons for the great importance of this element.
40. Name and describe three methods for the preparation of oxygen. Designate which one is the usual laboratory method and diagram the apparatus employed.
41. In the preparation of oxygen from potassium chlorate what is the purpose of the manganese dioxide? What is such an agent called?
42. How is oxygen collected? Why is it collected in this way? What is the test for it?
43. How is oxygen prepared commercially? What are its uses?

44. Name the physical properties of oxygen.
45. Describe the chemical activity of oxygen at *a*) ordinary temperatures, *b*) higher temperatures. Give illustrations in each case.
46. Define oxidation. By what is oxidation always accompanied? Give several examples of oxidation.
47. Define combustion, combustible substance, supporter of combustion, kindling temperature. Name two substances having low kindling temperatures.
48. In continuous combustion what source of heat maintains the substance at its kindling temperature?
49. What is the purpose of drawing air *a*) over the top of a furnace fire? *b)* through the fire from below? Explain.
50. Define oxide. Give the chemical composition of the following oxides: water, sand, lime, emery.
51. How does the weight of the products of combustion of a substance compare with the weight of the substance before combustion has taken place? How do you account for this weight change? Describe an experiment to verify your statements.
52. How does combustion in air and in oxygen differ? How do we know in the case of air that oxygen is the supporter of combustion?
53. Is oxygen always necessary for combustion? Define combustion in the broad sense.
54. What are the causes of spontaneous combustion? Give several examples. Why is oily waste kept in metal containers?
55. Note the fact that the following processes are chiefly processes of oxidation: decay of organic matter, drying of paint, rusting of iron, combustion of coal and other fuels, corrosion of metals, bleaching of colored fabrics, the maintenance of the heat of the body, the antiseptic action of hydrogen peroxide, changing of cider to vinegar, the lighting of a match.
56. Why will not some substances such as water, lime, and asbestos burn?

57. Name several commercial uses of oxygen.
58. Why are many iron structures protected by paint? Why do substances oxidize more rapidly at the seashore than in a desert?

OZONE

59. How may ozone be prepared? Of what does it consist?
60. When oxygen is converted into ozone, what is the volume relation between the oxygen taken and the ozone formed?
61. What are the physical and chemical differences between oxygen and ozone?
62. In what respect are oxygen and ozone identical? To what, then, must we attribute their different properties?
63. Name several important uses of ozone.
64. What is meant by allotropy, or allotropic forms of matter?

MEASUREMENT OF GAS VOLUMES

NOTES:—The volume of a given quantity of gas depends upon two factors—temperature and pressure. It is easy to understand that if we increase the temperature of a definite weight of gas its volume will expand and if we increase the pressure on a confined gas its volume will diminish. In other words, the volume of a gas varies directly—*i.e.* in the same direction—with the change of temperature and inversely—*i.e.* in opposite direction—with the change of pressure. These facts are summarized in the following laws:—

Charles' Law:—The volume of a gas varies directly as the *absolute* temperature, pressure remaining constant.

Boyle's Law:—The volume of a gas varies inversely as the pressure, temperature remaining constant.

In the former of these laws the term absolute temperature is used. This means the temperature reckoned from absolute zero, which is 273 degrees below ordinary zero. It has been found that for every degree the temperature of a gas rises above zero the volume of the gas is increased by one-two hundred seventy-third of the volume which it occupied at zero, and also that for every decrease of one degree in temperature the volume of the gas is decreased by one-two hundred seventy-third of its volume at zero provided the pressure remains constant.

Therefore in calculating the new volume of a gas which has undergone a change of temperature it is necessary first to change the ordinary temperatures to absolute temperatures. This is done by adding 273° to the ordinary reading. Thus the absolute temperature of 20° C. is $273° + 20° = 293°$.

Now apply Charles' Law:—Suppose we have 100 c.c. of oxygen at 20° C. and wish to find its volume at 40° C. pressure remaining constant.

$20° + 273° = 293°$ Abs. T. of 20° C.

$40° + 273° = 313°$ Abs. T. of 40° C.

Now ask yourself the question:—Does this change of temperature increase or decrease the volume of the gas? Then make a fraction, using the absolute temperatures found as numerator and denominator, which when multiplied by the original volume will give the required change.

Thus in the above example since the temperature is being increased the volume will be increased and the new volume will be $^{313}/_{293}$ times the original volume.

$100 \times {}^{313}/_{293} = 106.8$ c.c. new volume.

As to pressure it is apparent from Boyle's law that if we double the pressure on a gas we halve its volume or if we halve the pressure we double its volume. We express the pressure of a gas in millimeters of mercury, which means the number of millimeters of mercury which the pressure of a gas will sustain. At sea level the atmosphere

will sustain a column of mercury which is on an average 760 millimeters in height. This pressure, measured by 760 millimeters of mercury, is called one atmosphere.

Now to apply Boyle's law:—Suppose we have 100 c.c. of nitrogen at a pressure of 720 millimeters and we wish to find its volume at 750 millimeters, temperature remaining constant.

First ask yourself the question:—Does this change of pressure increase or decrease the volume of the gas?

Then make a fraction, using the two pressures as numerator and denominator, which when multiplied by the original volume will give the required change.

Thus in the foregoing example since the pressure is being increased the volume will be decreased and the new volume will be $^{720}/_{750}$ times the original volume.

$$100 \text{ c.c.} \times {}^{720}/_{750} = 96 \text{ c.c. new volume.}$$

Now suppose we wish to find the new volume of a gas when both the temperature and the pressure change:—

Find the volume of 100 c.c. of carbon dioxide when its pressure changes from 730 m.m. to 760 m.m. and its temperature from 20° C. to 30 C.

$$20° + 273° = 293° \text{ Abs. T. of } 20° \text{ C.}$$
$$30° + 273° = 303° \text{ Abs. T. of } 30° \text{ C.}$$

Now arrange the work as follows:—

$$100 \text{ c.c.} \longrightarrow \text{x c.c.}$$
$$293° \longrightarrow 303°$$
$$730 \text{ m.m.} \longrightarrow 760 \text{ m.m.}$$

Since the temperature change increases the volume the temperature fraction will be $^{303}/_{293}$. And since the pressure change decreases the volume the pressure fraction will be $^{730}/_{760}$.

Therefore,

$$100 \times {}^{303}/_{293} \times {}^{730}/_{760} = 99.3 \text{ c.c. new volume.}$$

Standard Conditions:—For accuracy and convenience in the measurement of gas volumes and their comparison, standard conditions of temperature and pressure have been adopted. These are 760 m.m. and 0° C. Therefore in reducing a gas volume to standard conditions of tempera-

ture and pressure it is necessary to find what the volume will be at 760 m.m. and 0° C.

For example, a certain quantity of hydrogen occupies 10 liters at 24° C. and 740 m.m.; find its volume at standard conditions.

$$24° + 273° = 297° \text{ Abs. T. of } 24° \text{ C.}$$
$$0° + 273° = 273° \text{ Abs. T. of } 0° \text{ C.}$$

Now,

$$10 \text{ l.} \longrightarrow x \text{ l.}$$
$$297° \longrightarrow 273°$$
$$740 \text{ m.m.} \longrightarrow 760 \text{ m.m.}$$

$10 \times {}^{273}\!/_{297} \times {}^{740}\!/_{760} = 8.95$ liters volume at standard conditions.

A gas which is under atmospheric pressure is under the pressure indicated by the barometer at that place and at the time the measurement is made.

Gases are usually collected over mercury or water. When collected over mercury in order to have the gas under barometric pressure, *i.e.*, what the barometer reads at that time, it is necessary that the levels of mercury inside and outside the tube in which the gas is confined be the same.

Suppose the mercury level is 20 m.m. higher inside the tube than it is outside, then the atmospheric pressure is doing two things. It is supporting the column of mercury 20 m.m. high and the balance of it is pressing upon the gas. Therefore the pressure of the gas is the barometric reading minus 20 m.m., and to find the pressure of a gas in such a case subtract the height of the mercury level inside the tube above the level outside from whatever the barometer reading may be.

Example:—A quantity of gas confined over mercury measures 45 c.c. under the following conditions:—height of mercury inside the tube 20 m.m. above the level outside, barometer reading 756 m.m., temperature 19° C. Find the volume at standard conditions.

$$19° + 273° = 292° \text{ Abs. T. of } 19° \text{ C.}$$
$$0° + 273° = 273° \text{ Abs. T. of } 0° \text{ C.}$$

$756 \text{ m.m.} - 20 \text{ m.m.} = 736 \text{ m.m.}$ actual P. of gas.

$$45 \text{ c.c.} \longrightarrow x \text{ c.c.}$$
$$292^\circ \longrightarrow 273^\circ$$
$$736 \text{ m.m.} \longrightarrow 760 \text{ m.m.}$$

Therefore,

$$45 \times {}^{273}\!/_{292} \times {}^{736}\!/_{760} = \text{new volume.}$$

In the case of a gas collected over water another factor called *aqueous pressure* must be taken into account. Since water vaporizes at all temperatures a gas confined over water will always contain some water vapor. And since this water vapor itself exerts a pressure, not all of the pressure indicated by the barometer will be due to the gas alone but a part to the water vapor. Therefore to find the pressure exerted by a gas confined over water it is necessary to subtract from the barometer reading the aqueous pressure expressed in millimeters of mercury.

Since the aqueous pressure is always the same for any given temperature, tables have been prepared showing the aqueous pressure at different temperatures.

Before taking the volume of a gas collected over water the levels of water inside and outside the tube must be made the same. Why?

Example:—The observed volume of a quantity of oxygen collected over water is two liters when the barometer reads 750 m.m., and the temperature is 20° C. Find the volume at standard conditions.

$$20^\circ + 273^\circ = 293^\circ \text{ Abs. T. of } 20^\circ \text{ C.}$$
$$0^\circ + 273^\circ = 273^\circ \text{ Abs. T. of } 0^\circ \text{ C.}$$
$$17.4 \text{ m.m.} = \text{aqueous pressure at } 20^\circ \text{ C.}$$
$$\therefore 750 - 17.4 = 732.6 \text{ m.m. actual pressure of gas.}$$
$$2 \text{ l.} \longrightarrow x \text{ l.}$$
$$293^\circ \longrightarrow 273^\circ$$
$$732.6 \text{ m.m.} \longrightarrow 760 \text{ m.m.}$$
$$2 \times {}^{273}\!/_{293} \times {}^{732.6}\!/_{760} = \text{new volume.}$$

In calculating changes in gas volumes with changes of temperature and pressure it is necessary for the pupil to bear clearly in mind the following steps:—First change ordinary temperatures to absolute temperatures; second, determine the actual pressure which the gas exerts, taking

into account differences of mercury level or aqueous pressure if necessary; and third, ask the questions: Do these changes of temperature and pressure respectively increase or decrease the volume of the gas? Then make fractions which when multiplied by the original volume will produce the required changes.

Another type of problem which frequently occurs has to do with the weight change that results in a given volume of gas from a change in its temperature and pressure. But here, too, the same principles apply.

Let us consider first the effect of a change of temperature on the weight of 1 liter of oxygen. One liter of oxygen at standard conditions weighs 1.43 grams. Now suppose we wish to find the weight of a liter at 20° C. It is perfectly evident that with an increase of 20 degrees in temperature the gas will expand and therefore a liter of it will not weigh as much as a liter did at zero degrees, because there will not be as much gas to weigh. Therefore, just as before we find the absolute temperatures of 20° C. and 0° C. and make a fraction from these numbers, which when multiplied into 1.43 grams will make the weight less.

Thus,

$$1.43 \times {}^{273}\!/_{293} = 1.33 \text{ grams.}$$

Let us next consider the effect upon the weight of 1 liter of oxygen of a change of pressure from 760 m.m., or standard pressure, to a pressure of 800 m.m. Here again it must be evident that, since an increase of pressure diminishes the volume of a gas, we shall have a greater mass of gas forced into a given space than we had before. Therefore at 800 m.m. of pressure a liter of oxygen will weigh more than it does at 760 m.m. Accordingly we make a fraction from these numbers which when multiplied into 1.43 grams will increase the weight.

Thus,

$$1.43 \times {}^{800}\!/_{760} = 1.50 \text{ grams.}$$

If the gas is subjected to both changes at the same time, the statement and solution will be as follows:—

$$1.43 \text{ g.} \longrightarrow x \text{ g.}$$
$$273° \longrightarrow 293°$$
$$760 \text{ m.m.} \longrightarrow 800 \text{ m.m.}$$
$$1.43 \times {}^{273}\!/_{293} \times {}^{800}\!/_{760} = 1.40 \text{ grams.}$$

PROBLEMS

I. PRESSURE ALONE CHANGING

65. A certain quantity of gas measures 800 c.c. when the barometer reads 740 m.m. What will be its volume when the barometer rises to 750 m.m.?
66. A volume of air measures 10 l. at a pressure of 800 m.m. Find its volume at 760 m.m.
67. The pressure of 1,000 c.c. of gas is increased from 500 m.m. to 800 m.m. Find the new volume.
68. The pressure on 100 c.c. of gas is 2 atmospheres. What will the volume be at 1 atmosphere? At ½ atmosphere? At 3 atmospheres?
69. If 50 c.c. of oxygen are confined in a gas measuring tube over mercury with the level of mercury 15 m.m. higher inside the tube than outside and the barometer reading 755 m.m., what will be the volume at standard pressure?
70. 100 c.c. of hydrogen are collected over water, the water levels being the same inside and outside of the measuring tube. If the barometer reads 740 m.m. and the temperature is 20° C., what will the volume be when the barometer reads 760 m.m., temperature remaining constant?
71. Reduce the following volumes to the volumes at standard pressure:—

500 c.c.	at	720 m.m.
5 l.	at	850 m.m.
100 c.c.	at	380 m.m.
340 c.c.	at	570 m.m.
1,000 c.c.	at	1,140 m.m.

II. TEMPERATURE ALONE CHANGING

72. If a certain mass of oxygen occupies 300 c.c. at 20° C. what will its volume be at 0° C.? At 10° C.? At 40° C.? At –10° C.?
73. A mass of gas at 0° C. occupies 500 c.c. Find its volume at *a*) 20° C., *b*) –15° C., *c*) 25° C., *d*) –8° C.
74. The observed volume of a certain mass of oxygen is 248 c.c. when the temperature is 18° C. What will be the volume when the temperature changes to 22° C.?
75. If 100 c.c. of gas are heated from 15° C. to 25° C., what will the new volume be?
76. If 1 l. of gas at 20° C. is heated until the volume is doubled what will the new temperature be?
77. Reduce the following volumes to the volumes at standard temperature:—

100 c.c. at 20° C.
10 l. at –25° C.
500 c.c. at 75° C.
230 c.c. at 19° C.
44 c.c. at 18° C.

III. TEMPERATURE AND PRESSURE BOTH CHANGING

78. A certain mass of gas measures 120 c.c. at 21° C. and 730 m.m. What will be its volume at 18° C. and 740 m.m.?
79. Given 48 c.c. of gas at 15° C. and 770 m.m., what will be the volume at 20° C. and 750 m.m.?
80. Given 5.8 l. of gas at 25° C. and 774 m.m., what will be the volume at 15° C. and 760 m.m.?
81. Find the volume at standard conditions of a quantity of gas that measured 50 c.c. under the following conditions:—collected over mercury, mercury level inside measuring tube 20 m.m. above mercury outside, barometer 752 m.m., temperature of gas 18° C.
82. A quantity of oxygen is collected over water. After making the water levels inside and outside of the measuring tube the same the observed volume is 43 c.c.

If the temperature of the gas is 18° C. and the barometer reads 768 m.m., what will the volume be at standard conditions of temperature and pressure? (Aqueous pressure at 18° C. = 15.3 m.m.)

83. Reduce the following volumes to standard conditions of temperature and pressure:—

340 c.c. at 12° C. and 753 m.m.
450 c.c. at 19° C. and 744 m.m.
10 l. at 25° C. and 780 m.m.
1,000 c.c. at 22° C. and 720 m.m.
275 c.c. at −10° C. and 800 m.m.

IV. MISCELLANEOUS GAS PROBLEMS

84. One liter of nitrogen at standard conditions weighs 1.25 grams. What will a liter of this gas weigh at 20° C. and a pressure of 720 m.m.?
85. If 100 c.c. of oxygen weigh 0.1403 grams at 20° C. and 800 m.m., what will 1 liter weigh at standard conditions?
86. What will be the weight of 1 liter of carbon dioxide at 18° C. and 740 m.m., if 50 c.c. weigh 0.098 grams at standard conditions?
87. A balloon at sea level contains 400,000 cubic feet of gas measured at a pressure of 774 m.m. of mercury and at a temperature of 27° C. It rises to an elevation at which the pressure is reduced to 430 m.m. and the temperature to −23° C. What is the volume of the gas under the latter conditions, assuming that none escapes?
88. A body of air at constant pressure occupies a volume of 500 c.c. at 20° C. At what temperature will its volume become 1,000 c.c.?
89. If 10 liters of hydrogen under standard conditions are heated to 27.3° C., without change in pressure, what will the new volume be?
90. What volume will 1 liter of gas at 136.5° absolute have at 136.5° C., pressure remaining the same?

91. What names are associated with the discovery of hydrogen?
92. In what state does hydrogen chiefly occur on the earth? Of what natural compounds is it a constituent?
93. Describe the preparation of hydrogen from water by means of the electric current.
94. Name two metals that liberate hydrogen from water at *a*) ordinary temperatures, *b*) at higher temperatures.
95. In the former of the two cases just named what evidence is there of chemical action? What becomes of the metal? What difference is there in the "feel" of the water before and after the experiment? How can it be shown that the water now contains a new substance? How can this substance be separated? What is its physical state? Is it an element, chemical compound, or mixture? What is its name? Its composition? Has the metal liberated all of the hydrogen from the water? How is the hydrogen collected?
96. The ancients regarded water as an element. How does the foregoing experiment disprove that idea?
97. Describe the preparation of hydrogen by the action of steam on iron.
98. In this experiment what sort of a chemical change has taken place?
99. Describe the preparation of hydrogen from acids.
100. What is the source of the hydrogen? What becomes of the metal? What new compound forms in the generating flask? Of what does it consist? How may it be separated?
101. Name three metals that liberate free hydrogen from acids and three that do not.
102. What two acids are generally used for this purpose? Name one acid that cannot be used.
103. How is hydrogen prepared commercially?

104. Name five physical properties of hydrogen. What is the approximate weight of one liter?
105. State the chemical activity of hydrogen at ordinary temperatures. Name three elements with which it may be made to combine and the product in each case.
106. How may it be shown that hydrogen is *a*) lighter than air? *b)* not very soluble in water? *c)* combustible? *d)* a non-supporter of combustion?
107. What is the product of the combustion of hydrogen? How can this be shown? How can one be sure that this product does not come from the generator?
108. Describe an experiment to show the great affinity of hydrogen for oxygen.
109. Name and define the chemical change that has taken place in the above experiment.
110. What sort of an agent is hydrogen? What has happened to the hydrogen? What other chemical change always accompanies reduction?
111. In the generation of hydrogen by the action of steam on iron, what chemical changes occur?
112. Describe the construction and operation of *a*) the oxyhydrogen blowpipe, *b*) the blast lamp. What are their uses?
113. What is the calcium or lime light?
114. Summarize the chemical properties of hydrogen. What is the test for it?
115. How would you prove by chemical means the presence of hydrogen in dry air, if the amount of hydrogen is too small to make the mixture explosive?
116. Name three important uses of hydrogen.
117. In what two ways may hydrogen be collected? Why may each of these methods be employed?
118. What determines whether a gas should be collected *a)* over water? *b)* by downward displacement of air? *c)* by upward displacement of air?
119. Define and illustrate *a*) oxidizing agent, *b*) reducing agent.
120. What forms of energy are manifest when a mixture

of hydrogen and oxygen is exploded? From what source are these forms of energy derived? Apply the law of conservation of energy to this reaction.

COMPOUNDS OF HYDROGEN AND OXYGEN

WATER

121. When and by whom was water proved to be a compound of hydrogen and oxygen?

122. Name two experiments that prove water to be a compound.

123. Describe the separation of water into its elements by means of the electric current. At which electrode does the hydrogen collect? the oxygen? What relation is found to exist between the volumes of the two gases?

124. Describe the eudiometer method for the exact synthesis of water. What volume corrections must be made before and after the explosion?

125. 30 c.c. of hydrogen are mixed with 40 c.c. of air that contains 20 per cent of oxygen and the mixture is exploded. What gases remain after the explosion and what is the volume of each? All of the gases are regarded as being at standard conditions of temperature and pressure.

126. Regarding all gas volumes as reduced to standard conditions, calculate from the following data the ratios both by volume and by weight in which oxygen and hydrogen unite to form water.

Volume of hydrogen taken	18.2 c.c.
Volume of hydrogen and oxygen	35.4 c.c.
Volume of oxygen left over	8.1 c.c.

(Oxygen is 15.88 times as heavy as hydrogen.)

127. Describe by aid of a labeled diagram the method used by Berzelius and Dumas for determining the

proportions by weight in which hydrogen and oxygen combine. State the precautions necessary in making this determination.

128. Calculate from the following data the ratio by weight of hydrogen and oxygen in water:—
Weight of copper oxide boat before heating 2.40 grams.
Weight of copper oxide boat after heating 1.70 grams.
Weight of calcium chloride tube before heating 15.30 grams.
Weight of calcium chloride tube after heating 16.09 grams.

129. What is the exact ratio by weight of hydrogen to oxygen in water?

130. Discuss the occurrence and the importance of water in nature.

131. What property of water makes absolutely pure water in nature impossible?

132. What two kinds of impurities may natural water contain? In what two ways may these impurities be held in the water?

133. What are some of the kinds of mineral matter commonly found in natural water and what are their sources?

134. What kinds of organic impurities are frequently found in water. With what sort of organisms are these impurities usually associated? To what diseases may these organisms lead?

135. Into what compounds does decaying vegetable and animal matter change? What conclusions, then, can be drawn from the presence of such compounds with reference to the fitness of water for drinking purposes?

136. What two kinds of water analyses are frequently made and what is the purpose of each?

137. Name four general methods for the purification of water.

138. Describe the simple distillation of water. Why does this process render water pure? Make a sectional diagram of the laboratory still.
139. What are the uses of distilled water?
140. What is fractional distillation?
141. Describe the simple filtration of water. What impurities are removed by this process?
142. Describe a sand filter for the purification of a city water supply. What substances are frequently placed between the layers of sand to assist in the purification? What impurities do they remove?
143. What sort of impurities does water filtered as above still contain?
144. From what sort of matter will artesian water usually be free? What will it still contain, and frequently in large quantities?
145. Compare the boiling and freezing of water as means of purification.
146. Discuss the chemical purification of water by means of *a*) ozone, *b*) chlorine, *c*) copper sulphate.
147. What is the effect of *aëration* upon water and how is it accomplished? How may water purify itself?
148. Describe a plant for the purification of a city water supply that shall employ *a*) sedimentation, assisted by a coagulum formed from lime and alum, *b)* aëration.
149. Why is it of fundamental importance to control the watershed of a city water supply?
150. What are the temperatures of boiling, freezing, and greatest density of water? Name other physical properties of water. What is the weight of 1 c.c. of water? 1 liter?
151. What are the chemical properties of water?
152. What is meant by *a*) heat of formation, *b*) heat of decomposition? Illustrate by reference to water.
153. What is water of crystallization? How may its presence be shown?
154. What is a hydrate?

155. How may it be shown that water of crystallization is in chemical combination with a salt?
156. Define *a*) efflorescent salt, *b*) deliquescent salt. Describe experiments to show whether a salt is efflorescent or deliquescent.
157. Name *a*) an efflorescent salt, *b*) a deliquescent salt, *c*) one that is neither efflorescent nor deliquescent.
158. What is mechanically enclosed water? How may its presence be detected?

HYDROGEN PEROXIDE

159. How does hydrogen peroxide differ in composition from water?
160. How may hydrogen peroxide be prepared?
161. State the physical properties of hydrogen peroxide. What is its chief chemical property? Why should it be kept in dark colored bottles and in a cool place?
162. In what form is hydrogen peroxide sold by druggists?
163. What is an antiseptic? To what are the antiseptic properties of hydrogen peroxide due?
164. Name an important commercial use of hydrogen peroxide.

THE ATOMIC THEORY

165. What man put forth the atomic hypothesis as an explanation of the facts of chemical observation?
166. What assumptions did he make as the basis of his hypothesis?
167. Define *a*) molecule, *b*) atom.
168. State and illustrate the law of conservation of matter. Show how the assumptions of the atomic hypothesis support this law.

169. State the law of definite composition, or definite proportions. Using water as an example illustrate its meaning. Show how the atomic hypothesis explains this law.

170. State the law of multiple proportions. Using water and hydrogen peroxide as examples illustrate its meaning. Show how this law is also explained by the atomic hypothesis.

171. What is meant by the atomic weights of the elements? What element is taken as the standard for atomic weights? Why?

172. What does it mean to say that the atomic weight of sulphur is 32.06?

173. Common limestone is a chemical compound of the elements, calcium, carbon, and oxygen. If the percentages of calcium in two samples of this substance are 40 per cent and 38 per cent respectively, what conclusion should you draw in regard to the specimens? State the law upon which your conclusion is based.

CHEMICAL EQUATIONS AND CALCULATIONS

174. Define *a*) atom, *b*) molecule, *c*) symbol.

175. How may symbols be used to represent a molecule of a compound? Illustrate.

176. Define formula. Give the formulae of three common compounds. In each case for exactly what does the formula stand?

177. Write and learn the formulae for the following compounds:—water, mercuric oxide, potassium chlorate, manganese dioxide, hydrochloric acid, sulphuric acid, sodium hydroxide, potassium hydroxide, hydrogen peroxide, copper oxide, calcium chloride, magnesium oxide, carbon dioxide, sulphur dioxide, phosphorus pentoxide.

178. What is a chemical reaction? Give two illustrations.
179. What is a chemical equation? Give two illustrations.
180. Write equations for the following chemical reactions using formulae throughout:—

Mercuric oxide + heat =
Potassium chlorate + heat =
Water + electrical energy =
Iron + sulfur =
Water + sodium =
Water + potassium =
Magnesium + oxygen =
Copper oxide + hydrogen =
Zinc + hydrochloric acid =
Iron + sulfuric acid =
Oxygen + electrical energy =

181. Express each of the above equations in words.
182. What is meant by balancing an equation? Why is this necessary?
183. What work and knowledge must precede the writing of a chemical equation?
184. What law of matter does every chemical equation illustrate?
185. Discuss and illustrate with two examples of each the following types of chemical reactions:—*a*) direct combination, or addition, *b*) simple decomposition, *c*) substitution, or replacement, *d*) double decomposition, *e*) oxidation and reduction.
186. In using a symbol to express the molecule of an *elementary* gas, what is the significance of the sub-2 written after the symbol?
187. Taking as an example the equation,

$$2\,H_2O = 2\,H_2 + O_2$$

show what is meant by the statement, "Chemical equations are quantitative."
188. What part do the atomic weights of the elements play in the quantitative side of chemical equations? Illustrate this by reference to the decomposition of potassium chlorate.

189. What is the molecular weight of a compound? How is it obtained?

190. What is a gram molecule?

191. Show how the percentage composition of a compound may be determined from its formula and molecular weight.

192. Calculate the percentage composition of each of the following compounds:—HgO, H_2O, $KClO_3$, MnO_2, HCl, H_2SO_4, $CuSO_4 . 5H_2O$.

NOTE:—Suppose we wish to find the weight in grams of oxygen which can be obtained from heating 25 grams of mercuric oxide. The steps are as follows:—First write the chemical equation, being sure that it is correct. Place over the formula of mercuric oxide in the equation the weight in grams of that substance and over the symbol for oxygen x g., the weight in grams of that element to be found. Now place under the formula for mercuric oxide its molecular weight and under the symbol for oxygen *two times* its atomic weight. Finally make a proportion in which the actual weights in grams of the substances being considered are to each other as their respective molecular weights.

Thus,

$$\begin{array}{rcl} 25\text{ g.} & & \text{x g.} \\ 2HgO & = 2Hg + & O_2 \\ 432 & & 32 \end{array}$$

$$25 : x = 432 : 32.$$

Again, suppose we wish to find the number of grams of hydrogen that will be liberated by the action of dilute sulfuric acid on 10 grams of zinc.

$$\begin{array}{rcl} 10\text{ g.} & & \text{x g.} \\ Zn + H_2SO_4 & = ZnSO_4 + & H_2 \\ 65.4 & & 2 \end{array}$$

$$10 : x = 65.4 : 2.$$

Note that the molecular weights need be found only for those substances being considered in the problem.

Again suppose we wish to find the weight of sulfuric acid that will be needed to combine with 10 grams of zinc.

$$\begin{array}{l} 10\text{ g.} \quad x\text{ g.} \\ Zn + H_2SO_4 = ZnSO_4 + H_2 \\ 65.4 \quad 98 \end{array}$$

$$10 : x = 65.4 : 98.$$

Or suppose we wish to find the weight of zinc sulfate formed by the action of sulfuric acid on 10 grams of zinc.

$$\begin{array}{l} 10\text{ g.} \quad x\text{ g.} \\ Zn + H_2SO_4 = ZnSO_4 + H_2 \\ 65.4 \quad 161.4 \end{array}$$

$$10 : x = 65.4 : 161.4.$$

Suppose we wish to find the weight of zinc necessary to liberate from sulfuric acid 10 grams of hydrogen.

$$\begin{array}{l} x\text{ g.} \quad 10\text{ g.} \\ Zn + H_2SO_4 = ZnSO_4 + H_2 \\ 65.4 \quad 2 \end{array}$$

$$x : 10 = 65.4 : 2.$$

193. To what numbers are the actual weights involved in a chemical equation proportional?

194. Are chemical equations algebraic? Explain.

195. How is water of crystallization represented in a formula? Illustrate.

196. What is meant by the heat of reaction? Of what two kinds may it be? In what unit is it measured? Define the unit.

197. What facts concerning a chemical reaction are not indicated by the equation expressing it? Illustrate by two examples.

PROBLEMS

198. From 108 g. of mercuric oxide how many grams of oxygen can be obtained? How many grams of mercury?

199. By the action of 46 g. of sodium upon water how many grams of hydrogen will be liberated? How many liters will this gas occupy at standard condi-

tions? What will the volume be at 20° C. and 740 m.m.?

200. In the above problem how many grams of sodium hydroxide will be formed?

201. What weight of oxygen will be generated by the decomposition of 50 g. of $KClO_3$? What will be its volume at 0° C. and 760 m.m.? at 18° C. and 770 m.m.?

202. In the above problem what weight of potassium chloride will be left in the generating flask?

203. What weight of P_2O_5 will be formed from burning 15.5 g. of phosphorus in oxygen? What weight of oxygen will be required? How many liters will this occupy at standard conditions?

204. How many grams of water of crystallization are there in the crystallized copper sulfate obtained from 31.8 g. of copper?

205. What weight of $FeSO_4$ will be formed by the action of sufficient H_2SO_4 on 14 g. of iron? How many liters of hydrogen measured at 20° C. and 750 m.m. will be evolved?

206. What weight of zinc will be required to liberate 4 g. of hydrogen from hydrochloric acid? What weight of acid will be needed and what weight of zinc chloride will be formed?

207. Calculate the percentage composition of *a*) $FeSO_4$, *b*) $ZnCl_2$, *c*) P_2O_5.

208. How many grams of copper oxide will be formed by heating 16 g. of copper in oxygen? How many grams of hydrogen will be required to reduce the copper oxide formed and what weight of water will result?

209. Calculate the percentage of oxygen in crystallized copper nitrate, $Cu(NO_3)_2 . 6H_2O$.

210. Define mass, weight, density.
211. What is specific gravity?
212. What is the unit of mass? How is it determined?
213. What is the weight of *a*) 50 c.c. of pure water? *b*) 1 liter?
214. When we say that the density of sulfuric acid is 1.84, what do we mean?
215. If the weight in grams and the density of a solid or liquid are known how may its volume be found?

PROBLEMS

216. If 50 c.c. of wood weigh 25 grams what is the density of the wood?
217. How many cubic centimeters of H_2SO_4, density 1.84, will be required in order to obtain 36.8 grams of the acid?
218. The density of mercury is 13.6. What is the weight of 1 liter?
219. The density of nitric acid is 1.56. Find the weight of 25 c.c. How many cubic centimeters will there be in 312 grams?
220. What is the volume of 3.2 kg. of alcohol having a density of 0.80?
221. What weight of H_2SO_4 will be required to dissolve 32.7 g. of zinc? If the density of the acid is 1.84, find the number of cubic centimeters.
222. What weight of hydrochloric acid gas will be required to combine with 10 g. of iron? How many cubic centimeters of hydrochloric acid solution, density 1.1 and containing 20 per cent pure acid by weight, will be required?
223. What will be the weight of 2 liters of alcohol having a density of 0.80?

224. What names are associated with the discovery and naming of nitrogen? Why was it given the name nitrogen?
225. In what state does nitrogen occur in the atmosphere? What percentage by volume of the atmosphere is nitrogen?
226. Where and in what compounds does nitrogen occur in the combined state?
227. Describe two methods for obtaining nitrogen from the air. Why is nitrogen obtained from the air impure?
228. From what compound of the element may pure nitrogen be obtained and in what way?
229. Name the physical properties of nitrogen.
230. What can be said of the chemical activity of nitrogen?
231. Under what circumstances may nitrogen be made to combine with *a)* certain elements such as magnesium? *b)* oxygen? *c)* hydrogen?
232. Name three important uses of nitrogen. Give two reasons for the very great economic importance of nitrogen compounds.
233. Name the rare elements of the atmosphere. What experimental fact led Lord Rayleigh to suspect their presence? Tell the story of Sir William Ramsay and the discovery of these rare gases.
234. What percentage of the atmosphere do the rare elements comprise? Which one is present in largest proportion?
235. Name an important use of *a*) argon, *b*) helium. What is the present source of helium? of argon?
235*a*. By what tests could you distinguish between oxygen, hydrogen, and nitrogen?

236. By what experiments could you demonstrate that air is not an element?
237. Name the constituents of the atmosphere and so far as possible the relative proportion of each.
238. How may the presence of each of the following constituents be proved:—oxygen? carbon dioxide? water vapor? nitrogen?
239. State the functions of each of the essential constituents of the atmosphere.
240. What is meant by the "fixation of atmospheric nitrogen"? Why is fixation of nitrogen of very great importance to man? Describe two methods, one natural and one artificial, by which free nitrogen may be changed to fixed nitrogen.
241. Describe the laboratory method by which you determined the percentage of oxygen in the air. What temperature and pressure readings were made and how did you use them? What is the volume percentage of oxygen in air?
242. How may the percentage of nitrogen be determined? What is the percentage?
243. What is the average percentage of carbon dioxide in the air? Why does the actual percentage vary from time to time and place to place, although the average remains constant?
244. What are the chief factors which determine whether or not air is healthful to breathe?
245. Why does the air of a tightly closed room, in which lamps are burning, become unfit to breathe?
246. Why does a lamp burn better with the chimney on than with it off?
247. Show the effects of each of the following processes upon the composition of the atmosphere:—*a*) respiration, *b*) combustion, *c*) action of plants.
248. Trace the cycle of carbon in nature, showing how in the form of carbon dioxide and under the influence

of sunlight it is used as plant food and how it is eventually restored to the air to repeat the cycle of changes.

249. Do growing plants increase or decrease the amount of oxygen in the air?

250. Give reasons for the great constancy of composition of the atmosphere. Is its composition always perfectly uniform?

251. Give three conclusive reasons for believing that the air is a mechanical mixture and not a chemical compound.

252. How may a gas be liquefied?

253. Describe the construction and operation of a machine for the liquefaction of air.

254. What is meant by the critical temperature of a gas?

255. Name two men who did much of the early work on the liquefaction of gases.

256. Describe the construction and explain the efficiency of a container in which liquid air may be kept for limited periods of time.

257. What is the boiling point of liquid air? Which gas passes off first? Why? What does this prove concerning the nature of air?

258. In what important industry associated both with peace and war is the liquefaction of air a fundamental part? In what way?

259. Name other uses of liquid air. In what way is it related to the incandescent lamp industry? the manufacture of fertilizers?

260. What important point is suggested by the fact that when oxygen and nitrogen are mixed in proportion to form air no heat change occurs?

261. Since the atmosphere consists so largely of nitrogen, why is it that this element is not more abundantly found in the minerals of the earth's crust?

262. How many grams of oxygen will be required to burn 2 grams of phosphorus? How many liters of oxygen at standard conditions will be required? How

many liters of air will be needed to obtain this volume of oxygen?

263. How many liters of oxygen will be required to burn 10 liters of hydrogen? How many liters of air? How many liters of water vapor will be produced?

SOLUTIONS AND IONIZATION

264. Define *a*) solution, *b*) solvent, *c*) solute.
265. To what three classes of matter may the solute belong?
266. Name three characteristics of solutions.
267. State and illustrate how each of the following conditions affects the solubility of a gas:—*a*) nature of the gas, *b*) nature of the liquid solvent, *c*) pressure, *d*) temperature.
268. Describe a simple experiment for showing the degree of solubility of a gas in water.
269. Describe two methods for showing the presence of dissolved air in tap water.
270. How may most dissolved gases be expelled from water?
271. Define effervescence. How do you account for the effervescence observed in a glass of soda water?
272. Name a gas that gives a colored solution.
273. Name three gases that are only slightly soluble in water and two that are very soluble.
274. State how each of the following conditions affects the solubility of a solid:—*a*) nature of the solid, *b*) nature of the solvent, *c*) temperature. Illustrate each answer.
275. How will each of the following hasten the process of solution:—*a)* pulverizing? *b)* stirring?
276 What liquid is the most general solvent? the second in solvent power?
277. Point out how the degrees of solubility of each of the

following substances differ at 0° C. and 100° C. respectively:—*a*) calcium chloride, *b*) sodium chloride, *c*) potassium nitrate, *d*) copper sulfate, *e*) calcium hydroxide.

278. Distinguish between a saturated solution and an unsaturated solution.

279. Describe two ways in which a solution of sodium chloride, saturated at room temperature, may be prepared.

280. How can you determine whether or not a solution is saturated?

281. How may a saturated solution be changed to an unsaturated solution? An unsaturated solution to a saturated solution?

282. What is meant by the term solubility as applied to any particular substance?

283. What is a supersaturated solution? How may such a solution be prepared? In what two ways may a supersaturated solution be converted into a saturated solution?

284. Distinguish between the solution of a salt in water and the suspension of an insoluble powder in water. Describe the process by which you would separate each from the water.

285. How would you determine whether a colorless sample of water contains a dissolved solid?

286. How may a soluble salt be freed from soluble impurities?

287. What is an emulsion? Give examples. Distinguish solutions from suspensions and emulsions.

288. What is a colloidal solution? State the characteristics of such a solution. Name important applications of colloids in the industries.

289. How do the boiling and freezing points of a solution differ from those of the pure solvent? Upon what does the extent of this difference depend?

290. Define *a*) electrolyte, *b*) electrolysis.

291. Describe the apparatus used in the electrolysis of

solutions. What are *a)* the electrodes? *b)* the cathode? *c)* the anode?

292. Define *a*) dissociation, *b*) ion. Illustrate the meaning of these terms by reference to the solution in water of sodium nitrate and sodium chloride.

293. What do the ions bear? How does sodium in the form of ions differ from ordinary metallic sodium? To what must this difference be due?

294. What relation is there between the positive charges and the negative charges in a salt solution?

295. Represent by ionic equations the dissociation of NaCl, Na_2SO_4, $NaNO_3$, HCl, KCl, H_2SO_4.

296. Define non-electrolyte.

297. Describe a convenient form of apparatus and the process by which you could determine whether or not a solution is an electrolyte.

298. Name five electrolytes and two non-electrolytes.

299. Why is copper sulfate in aqueous solution decomposed by the electric current while sugar is not?

300. In what liquid do compounds most freely undergo dissociation?

301. How are the boiling and freezing points of solutions explained by the theory of electrolytic dissociation?

302. In the ionization of a salt which ion is always positive? which negative? In the case of an acid which ion is positive?

303. In the electrolysis of water what is the function of the sulfuric acid that is added? Describe the movement of the ions and the action at the electrodes.

304. In the electrolysis of sodium sulfate account for the formation of an acid at the anode and a base at the cathode. What gas is liberated at each electrode? Explain.

305. Between what do chemical reactions in solutions occur?

306. How do you account for the fact dilute solutions of $CuCl_2$, $CuBr_2$, $Cu(NO_3)_2$, $CuSO_4$, and all other copper salts are blue in color?

307. Upon what does the extent of dissociation in solution depend?
308. How does concentrated sulfuric acid differ from the dilute acid?
309. Describe the electrolysis of a copper sulfate solution.

ACIDS, BASES, AND SALTS

310. Into what three classes of chemical characters may the great majority of compounds be divided?
311. Name the three most common mineral acids. What are the formula and physical state of each?
312. Into what ions does each acid dissociate? What ion do the three acids possess in common? What, then, is the essential constituent of an acid?
313. How has it been shown that two of these acids contain hydrogen?
314. Name three acid indicators and state the color effect of acids upon each.
315. Name three characteristics of an acid. Define acid.
316. What is the effect of dissolving acids in a liquid, like benzene, which does not have the power of dissociating them into ions?
317. Name with formulae the three most common bases. What ones are called akalis?
318. Into what ions does each base named dissociate? What ion does each base possess in common? What, then, is the essential constituent of a base?
319. What color effect do bases have on the indicators named above?
320. Name three characteristics of a base. Define base.
321. In order that an acid or a base may exhibit its characteristic properties in what form must it be?
322. When an acid and a base in solution are brought together in equivalent proportions what is the effect upon the properties of the resulting solution?

323. In the above reaction what combination of ions has taken place? What new substance has been formed? What name is given to this process?
324. Define neutralization.
325. Express in the form of ionic equations the neutralization of three acids by three bases.
326. According to the ionization hypothesis what takes place upon evaporating the water from a neutralized solution of an acid and a base?
327. Define salt. Name the characteristics of a salt.
328. What is meant by "heat of neutralization"? To what is this heat due? What equality is there between the heats of neutralization with different acids and bases?
329. What is *a)* a normal solution of an acid? *b)* a normal solution of a base?
330. Upon the solution of an acid or a base in water do all of the molecules dissociate into ions? Upon what does the extent of dissociation depend? Upon what does the strength of an acid or a base depend? Explain.
331. Define *a)* basic salt, *b)* acid salt, *c)* normal salt. How may each be prepared? Write equations to illustrate the preparation of each.
332. Define radical. Give five examples.
333. What general name is given to all bases? How are they distinguished from each other? Distinguish between an hydroxide and a hydrate.
334. What is a binary acid? How are binary acids named? Illustrate. What are ternary acids? Illustrate.
335. In naming a series of ternary acids of the same element what is the significance of each of the following:—*a)* –ic? *b)* –ous? *c)* hypo–? *d)* per–?
336. Explain the method of naming the salts corresponding to the above prefixes and suffixes of acids.
337. What ending do binary compounds have? How are such compounds named? Illustrate.

338. Why will not concentrated sulfuric acid liberate hydrogen when acted upon by zinc, while dilute acid will?

339. According to the ionization hypothesis what happens when *a*) water is added to hydrochloric acid? *b*) water is added to sodium hydroxide? *c*) solutions of these two are mixed in the proper proportions to neutralize each other? *d*) the resulting solution is evaporated?

340. What weight of sodium hydroxide is required to neutralize 100 c.c. of a normal solution of hydrochloric acid?

341. How many grams of each of the following substances are required for the preparation of a normal solution of:—hydrochloric acid? sodium hydroxide? sulfuric acid?

VALENCE

342. How do the elements chlorine, oxygen, nitrogen, and carbon differ in their power to hold in combination the element hydrogen, as shown by the following formulae:—HCl, H_2O, NH_3, CH_4?

343. Define valence. What is the valence of each of the above elements?

344. What is *a*) a univalent element? *b*) a divalent element? *c*) a trivalent element? *d*) a tetravalent element?

345. Knowing that the valence of chlorine is one what is the valence of each of the other elements in the following compounds:—$CaCl_2$, $NaCl$, KCl, $FeCl_2$, $FeCl_3$, $CuCl$, $CuCl_2$, $MgCl_2$, $BaCl_2$, PCl_3, PCl_5, $PbCl_2$, $AgCl$, $HgCl$, $HgCl_2$, $AlCl_3$?

346. Give the valence of each radical in the following acids:—H_2SO_4, HNO_3, H_3PO_4, H_2CO_3, $H(C_2H_3O_2)$, H_2SO_3, HNO_2.

347. What is the name of the salt of each of the above acids?

348. How do we determine the formula of a compound consisting of *a*) two univalent elements? *b*) two divalent elements? *c*) two trivalent elements? *d*) a univalent and a divalent element? *e*) a univalent and a trivalent element? *f*) a divalent and a trivalent element? *g*) a divalent and a pentavalent element? Write a formula to illustrate each answer.

349. In every formula what relation must exist between the number of valence bonds of the two elements or radicals?

350. Write the graphic formulae of the following compounds:—H_2O, NH_3, CH_4, CO_2, SO_2, H_2O_2, N_2O_3, N_2O_5.

351. How many atoms of hydrogen will be replaced by *a*) a univalent element? *b*) a divalent element? *c*) a trivalent element?

352. With due regard to valence write equations for the complete neutralization of each of the following bases by each of the following acids:—NaOH, $Ca(OH)_2$, $Al(OH)_3$; HCl, H_2SO_4, H_3PO_4.

353. From what two sorts of chemical substances are all salts derived? In what respect does a salt differ from its acid? From its base? What part of an acid goes to form the salt? What part of the base?

354. What radical does every nitrate contain? every nitrite? every sulfate? every sulfite? every phosphate? every phosphite? every carbonate?

355. Write the formulae for the acids containing the foregoing radicals. What are their names and the valence of each radical?

356. Write the formulae of the calcium, sodium, and aluminum salts of these acids.

357. What relation is there between the valence of an element or radical and the number of charges of electricity which its ion is able to bear? What kind of charges do metallic ions bear? acid radicals?

358. Given the valence of A as three, derive the probable valences of B, C, and D from the following formulae:—A_2B_3, B_2C, B_5D_2. What would be the formula of a compound of A with C?

359. The atomic weight of a certain metal is 56. By experiment it is found that 28 grams of this metal replace 1 gram of hydrogen from hydrochloric acid. What is the valence of the metal in this reaction?

360. Write the formulae for the chlorides and sulfates of the two series of iron salts.

361. The valences of potassium, zinc, aluminum, and tin are 1, 2, 3 and 4, respectively. Write the formulae for the chlorides, carbonates, and phosphates of these metals.

COMPOUNDS OF NITROGEN

AMMONIA

362. Why do not compounds of nitrogen occur in great abundance in nature?

363. Where in nature does nitrogen occur in the combined state?

364. What compound of nitrogen results from the decomposition of organic matter by heat? In the commercial operation of this process what raw material is employed? What name is given to the process and how is it carried out?

365. What is the formula of ammonia? the valence of nitrogen?

366. What is the ammonium radical? its valence? How does it act in chemical reactions?

367. Write the formulae for ammonium chloride, ammonium nitrate, ammonium sulfate, and ammonium carbonate.

368. How may ammonia be liberated from an ammonium salt?

369. Describe the laboratory method for the preparation

and collection of ammonia. Diagram the apparatus and write the equations for the reactions.

370. Give two reasons for the manner of collecting ammonia.

371. Describe an experiment to show the great solubility of ammonia in water.

372. Give the names of three salts and three bases that may be used in the preparation of ammonia. Write equations showing all the possible combinations of these substances.

373. In the preparation of ammonia what ammonium compound first forms? Into what does this break down?

374. Describe the commercial manufacture of ammonia. Of what process is it a by-product? In what forms is it placed upon the market?

374*a*. Describe the production of ammonia from calcium cyanamide.

375. What important fertilizer is made from ammonia?

376. How may ammonia be prepared by direct union of the elements? Describe the *Haber Process* and point out its very great importance during the war.

377. Name four physical properties of ammonia.

378. What are its chemical properties?

379. Describe two tests for ammonia.

380. Name three uses of ammonia.

381. Describe the manufacture of artificial ice by the use of liquid ammonia. Why is brine used in this process?

382. What is the chemical nature of ammonium hydroxide? its formula? Into what ions does it dissociate in solution? What can be said of its stability? How is it prepared?

383. What are the differences between ammonia water and liquid ammonia?

384. In testing for ammonia gas with litmus paper why must the paper be moist?

385. How could you determine whether a sample of an unknown salt is an ammonium salt?

386. Distinguish between ammonia and ammonium. In what respect is the latter similar to a metal?

387. Calculate the weight of ammonia gas that can be obtained by the action of calcium hydroxide on 66 grams of ammonium sulfate. What volume will this occupy at standard conditions? at 20° C. and 740 m.m.?

388. How many liters of ammonia gas can be obtained from 20 grams of ammonium chloride, if the gas is measured at 21° C. and 750 m.m.?

389. What results when a solution of ammonium hydroxide is evaporated to dryness? a solution of hydrochloric acid is evaporated to dryness? a mixture of these two solutions is evaporated to dryness? Explain.

NITROGEN ACIDS

390. Give the names and formulae of the two nitrogen acids. What are the names of their salts?

391. What salts of nitric acid are found in nature? What are their common names?

392. How may nitric acid be liberated from its salts? Describe the laboratory preparation of nitric acid. Diagram the apparatus and write the equation for the reaction.

393. In the preparation of any acid with what must we start? Why do we use sulfuric acid so frequently? In what sense is sulfuric acid a strong acid? In what cases may we substitute some other acid for sulfuric?

394. Name three physical properties of nitric acid.

395. What is the most marked chemical property of nitric acid? What uses of the acid depend upon this property?

396. Write the equation for the decomposition of nitric acid under the influence of *a*) heat or sunlight, *b*) a reducing agent. What are always two products of the decomposition?

397. What is the cause of the brown color of nitric acid which has stood exposed to the light for some time?

398. What gas is usually set free by the action of an acid on a metal? What sort of an agent is this gas? What sort of an agent is nitric acid?

399. Considering, then, that nitric acid is always present in excess, why do we not get free hydrogen by the action of nitric acid on a metal?

400. Write the equation for the reaction of hydrogen with nitric acid. What gas is liberated?

401. Write the equation for the reaction of copper and nitric acid, assuming that hydrogen first forms. Now write the equation for the secondary reaction of hydrogen with nitric acid. Then combine the two equations into one.

402. State clearly why we do not get free hydrogen by the action of nitric acid on metals.

403. Summarize the chemical properties of nitric acid.

404. Give the chemical name and formula of the most abundant salt of nitric acid found in nature. Where is it found? What is its common name? Why has it been of such great importance? Why has this importance become somewhat diminished in recent years?

405. Describe one of the methods for manufacturing nitric acid directly from the nitrogen of the air. What is this process called? Of what very great importance was this general process to Germany during the war? Why is it still of great importance in times of peace?

406. By what natural method is atmospheric nitrogen "fixed"?

407. Show the importance of nitric acid and nitrates in the manufacture of explosives. Name three high explosives. What elements do they all contain? To what is their great violence due?

408. Name other commercial uses of nitric acid and

nitrates. What does the presence of nitrites and nitrates in water indicate?

409. Describe the visible effects of pouring concentrated nitric acid upon zinc. Explain the result.
410. Describe the nitrate test.
411. What weight of nitric acid can be obtained by the action of sufficient sulfuric acid on 8.5 tons of Chili saltpeter?

OXIDES OF NITROGEN

412. Write the names and formulae of the five oxides of nitrogen.
413. What is laughing gas? Describe its preparation. Write the equation.
414. State the physical properties of nitrous oxide. For what is it used?
415. What is the most marked chemical property of nitrous oxide? How may it be distinguished from oxygen?
416. Describe the preparation and collection of nitric oxide. Write the equation for the reaction. Why is not hydrogen obtained instead of nitric oxide?
417. State the physical properties of nitric oxide. What is its action with oxygen? What are the name and color of the product? What is the effect of allowing a bottle of nitric oxide to escape into the air?
418. Describe two methods for the preparation of nitrogen peroxide.
419. State the physical and chemical properties of nitrogen peroxide.
420. What two substances are formed by the solution of nitrogen peroxide in water?
421. Write equations for the reactions that occur when nitrogen trioxide and nitrogen pentoxide respectively are dissolved in water. What is formed in each case?
422. Into what may the two acids formed in the above reactions be decomposed?
423. Define acid anhydride.
424. Write the formulae for the series of nitrogen oxides

and by means of them prove the law of multiple proportions.

425. How many c.c. of nitric acid solution, density 1.4 and containing 68 per cent pure acid by weight, will be required to neutralize 28 grams of KOH?

426. What weight of nitric acid can be obtained from one ton of atmospheric nitrogen?

427. From 20 grams of NH_4NO_3 what weight and what volume of laughing gas can be obtained?

428. How many grams of copper will be required to yield 50 liters of nitric oxide?

REVERSIBLE REACTIONS AND CHEMICAL EQUILIBRIUM

429. $$3\ Fe + 4\ H_2O = Fe_3O_4 + 4\ H_2.$$
Under what circumstances will the above reaction go to the right? to the left? What kind of a reaction is it?

430. Write equations for three other similar reactions.

431. Using the above reaction or some other as an illustration explain the meaning of *chemical equilibrium.*

432. How do the relative masses of the reacting substances influence the direction in which a reaction will go? Illustrate by reference to the reaction of steam and iron.

433. Under what circumstances will a reversible reaction be complete? Illustrate by reference to the reaction under discussion.

434. Name with illustrations the three cases in which reversible reactions in solution may be complete.

435. How is the principle of reversible reactions applied in the preparation of *a)* ammonia? *b)* nitric acid?

436. Why will each of the following reactions go to completion?

$2Na + 2H_2O = 2NaOH + H_2$

$NaOH + HCl = NaCl + H_2O$

$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$

$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$

$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl$

$Pb(NO_3)_2 + H_2S = PbS + 2HNO_3$

$2NHOH + H_2SO_4 = (NH_4)_2\ SO_4 + H_2O$

437. Explain what is meant by *mass action.*
438. Why will concentrated HCl form a precipitate with a $BaCl_2$ solution? What is the precipitate?
439. Why will hydrochloric acid gas, when passed into a saturated solution of sodium chloride, precipitate this salt from the solution?
440. Define precipitate.

SULFUR

441. How does sulfur occur in nature?
442. Name five localities in which sulfur is found.
443. Describe the process for the extraction of sulfur employed in *a*) Sicily, *b*) Louisiana.
444. Where is the purest sulfur found?
445. What is *a)* roll sulfur? *b)* flowers of sulfur?
446. Name four physical properties of sulfur.
447. What is the best solvent for sulfur?
448. Describe the changes that take place on heating sulfur out of contact with the air and the reverse changes upon cooling.
449. What are the two forms of sulfur crystals? Describe the preparation of each.
450. At ordinary temperatures which is the more stable form of sulfur crystals? Above what temperature are monoclinic crystals stable?
451. What are the two varieties of amorphous sulfur? How is each prepared? Into what form does plastic sulfur change on standing?

452. Name two important chemical properties of sulfur. What other element does it resemble?
453. Name several metallic sulfides and state the commercial importance of these compounds.
454. Name five uses of sulfur and state its function in each case. Name the allotropic forms of sulfur.

HYDROGEN SULFIDE

455. Where is hydrogen sulfide found in nature? What is its formula? What is the valence of sulfur in this compound?
456. Describe the laboratory preparation of hydrogen sulfide. Diagram the apparatus and write the equation for the chemical reaction. What is the reason for the manner of collecting the gas?
457. What is the purpose of each of the substances used in this preparation?
458. Is this reaction reversible? complete? Give reasons.
459. In what respect is this reaction similar to the one which takes place when sulfuric acid acts on a nitrate? In what respect is it different? Why can hydrochloric acid be used in the former reaction instead of sulfuric?
460. Name four physical properties of hydrogen sulfide.
461. What is the chemical character of hydrogen sulfide? What is the name of its salts?
462. Complete and balance the following equations:—

$H_2S + NaOH =$
$H_2S + Pb(NO_3)_2 =$
$H_2S + AsCl_3 =$
$H_2S + SbCl_3 =$

463. Describe a laboratory experiment for showing the results of burning hydrogen sulfide in *a*) a complete supply of oxygen, *b*) an insufficient supply.
464. Illustrate the reducing action of hydrogen sulfide by

writing equations for its reaction with hydrogen peroxide and nitric acid.

465. Describe the action of the gas on such metals as copper and silver.

466. Summarize the chemical properties of hydrogen sulfide.

467. What is the test for hydrogen sulfide?

468. How may lead and copper sulfides be precipitated? Why are these reactions complete?

469. What is the cause of the tarnishing of silver? the blackening of white paint?

470. Hydrogen sulfide is passed into a dilute solution of lead nitrate until precipitation is complete, thus forming 2.37 g. of lead sulfide. How many grams of lead nitrate did the original solution contain?

471. Find the number of grams of sulfuric acid required to unite with 176 g. of iron sulfide to form hydrogen sulfide. Find the number of grams of hydrogen sulfide formed and the number of liters which this will occupy at standard conditions.

OXIDES OF SULFUR

472. Name with formulae the two oxides of sulfur. What are the valences of sulfur?

473. Where is sulfur dioxide found in nature?

474. Describe the preparation of sulfur dioxide from *a*) the element sulfur, *b*) a sulfide. Are these laboratory or commercial methods?

475. Describe the laboratory preparation of sulfur dioxide from sulfuric acid. What must be the condition of the acid? What gas is first liberated? What sort of an agent is this gas? How does it react with the excess of acid? Write two equations to show these changes.

476. Name another instance in which free hydrogen is not obtained by the action of a metal and an acid.
477. Describe the preparation of SO_2 from a sulfite. Diagram the apparatus and write the equation for the chemical reaction. Give reasons for the manner of collecting the gas.
478. Name four physical properties of sulfur dioxide.
479. Of what acid is sulfur dioxide the anhydride? What is its formula? What can be said of the strength and stability of this acid?
480. What are the salts of this acid called? What is the acid radical? its valence? Write the formulae for two of these salts.
481. Describe an experiment to show the reducing action of sulfurous acid. What acid forms when sulfurous acid is oxidized?
482. Describe an experiment to show the bleaching action of sulfurous acid. To what chemical property is this action due? What commercial uses are made of this action?
483. To what uses are the antiseptic properties of sulfurous acid put?
484. In liberating sulfurous acid from its salts why may an acid of low boiling point, such as hydrochloric, be used?
485. What is the greatest commercial use of sulfur dioxide?
486. What is a bisulfite? How is calcium bisulfite used in the manufacture of paper?
487. Describe the catalytic preparation of sulfur trioxide.
488. What are the physical and chemical properties of sulfur trioxide? Of what acid is it the anhydride?
489. Define catalyzer. Give examples of this kind of action.
490. What is the old name of sulfuric acid? Write its formula. Give the name of its salts.
491. Name at least four industries that use large quantities of sulfuric acid.

492. Describe the contact process of manufacturing sulfuric acid.
493. Name three substances that may be used as the catalytic agent. Why is Louisiana sulfur the best in the world for the manufacture of sulfuric acid by this process as well as by the chamber process?
494. Write the equations for the reactions that occur in the contact process.
495. What is fuming sulfuric acid?
496. In the chamber process of manufacturing sulfuric acid what is the significance of the name?
497. In the chamber process what is the source of the sulfur? Into what gaseous compound must the sulfur be converted? How is this done? With what is this gaseous compound mixed? What chemical change does it then undergo? What is the product and with what does it combine? What is formed?
498. What is the source of the oxides of nitrogen in the chamber process? What is their function? How are the reduced oxides of nitrogen regenerated? In what form do they finally escape from the last chamber? What is the function of the air used?
499. How many chambers are employed? With what are they lined? Why?
500. Describe each of the following as to construction, location, and use *a*) the Gay-Lussac tower, *b*) Glover tower. What is done with the acid coming from the bottom of each tower?
501. Why are the two towers filled with acid-resisting rock?
502. Write equations for the reactions involved in the lead chamber process.
503. About what per cent sulfuric acid can be obtained by this process? How can this be concentrated?
504. Name three important physical properties of sulfuric acid. What is it sometimes called? Why?
505. Illustrate the acid properties of sulfuric acid by writing equations for the following reactions:

$H_2SO_4 + CuO =$
$H_2SO_4 + Ca(OH)_2 =$
$H_2SO_4 + NaOH =$
$H_2SO_4 + Al(OH)_3 =$
$H_2SO_4 + Zn =$

506. In order to react readily in the above reactions in what form must the acid be? Why?
507. Under what circumstances will sulfuric acid act as an oxidizing agent?
508. What is the action of dilute sulfuric acid on such metals as zinc and magnesium? Write the equations involved.
509. Illustrate the action of hot concentrated sulfuric acid on metals by writing equations for its reaction with copper.
510. What is the action of sulfuric acid on salts of other acids? To what is this action due? Illustrate.
511. What is the action of the concentrated acid on water? What use is made of this property? What caution must be observed in mixing sulfuric acid and water?
512. What is the effect of concentrated sulfuric acid on such organic substances as sugar, wood, and cotton and woolen fiber? Explain.
513. Give three experimental ways by which dilute and concentrated sulfuric acid may be distinguished.
514. What name is given to the salts of sulfuric acid? What is the acid radical? its valence?
515. Give the chemical name and formula of *a*) oil of vitriol, *b*) blue vitriol, *c*) white vitriol, *d*) green vitriol, or copperas, *d*) Epsom salt, *e*) Glauber's salt, *f*) gypsum.
516. What is *a*) a mono-basic acid? *b*) a di-basic acid? *c*) a tri-basic acid? Give two examples of each.
517. How many salts are possible with each of the above acids? Select one acid of each type and write equations for the formation of all the possible sodium salts in each case.

518. What is meant by *a*) a mono-acid base? *b*) a di-acid base? *c*) a tri-acid base? Give examples.
519. What are the formula, properties, and uses of carbon disulfide?
520. What weight of sulfuric acid can be obtained from one ton of sulfur? What weight of 98 per cent acid?
521. What weight of sulfuric acid is necessary for the preparation of 22.4 liters of sulfur dioxide measured at standard conditions?
522. Show how SO_2 and SO_3 illustrate the law of multiple proportions.
523. What is the test for H_2SO_4? for any soluble sulfate?
524. How can you distinguish between a sulfide, a sulfite, and a sulfate?
525. Name the insoluble sulfates.
526. Name five important uses of sulfuric acid.

PERIODIC LAW

527. What two names are associated with the discovery of the generalization known as the periodic law?
528. Describe the arrangement of the elements in accordance with this law. What property of an element determines its position in the periodic table?
529. Where in the table are the rare elements of the atmosphere placed?
530. Starting with lithium and passing through the members of the first period show the gradation of properties from strongly basic to strongly acid-forming elements.
531. State the periodic law.
532. What constitutes a period? a group? a family?
533. In what respects do the elements of a given family resemble each other. Taking the phosphorus family as an example show the gradation of chemical and physical properties with increasing atomic weight.
534. Discuss the periodic law as to *a*) its value, *b*) its imperfections.

THE CHLORINE FAMILY

535. Name the members of the chlorine family and give the symbol of each. In what group of the periodic table do they occur?
536. In what state do these elements occur in nature? What name has been applied to them? Why?
537. As the atomic weights of these elements rise how do their properties vary with respect to *a*) melting and boiling points? *b*) color? *c*) physical state? *d*) affinity for hydrogen?
538. What is the valence of each? What compound with hydrogen does each form?

FLUORINE

539. In what compounds does fluorine occur in nature?
540. Why was the preparation of fluorine in the free state so extremely difficult? Give the name of the man who first prepared it and a brief description of his method.
541. What can be said of the chemical activity of fluorine? With what element will it not combine?
542. What are the physical properties of fluorine?
543. Describe the preparation of hydrofluoric acid. Write the equation for the chemical reaction.
544. State the physical and chemical properties of this acid. In what sort of containers must it be kept? Why?
545. What is the chief use of hydrofluoric acid? Write the equation for its reaction with SiO_2.

CHLORINE

546. Who discovered chlorine? Who proved it to be an element?
547. In what compounds is chlorine found in nature? What one is most abundant?
548. Describe the laboratory preparation of chlorine from

manganese dioxide and concentrated hydrochloric acid as to *a*) apparatus, *b*) collection of the gas, *c*) chemical changes taking place. Write the equations.

549. What sort of an agent is MnO_2 in this reaction?

550. Describe the preparation of chlorine starting with sodium chloride. Write the equations for the reactions.

551. Describe the commercial preparation of chlorine by the electrolysis of brine.

552. Name four physical properties of chlorine.

553. Discuss the chemical activity of chlorine with reference to its action on *a*) metals, as copper and sodium, *b*) non-metals, as antimony and arsenic, *c*) hydrogen, *d*) some compounds containing hydrogen, *e*) color substances.

554. How may it be shown that chlorine decomposes water? What is liberated?

555. In the bleaching action of chlorine why must the fabric be wet? What chemical changes occur? What really does the bleaching? Into what is the coloring matter changed by this action?

556. In what compound is chlorine placed upon the market for use as a commercial bleaching agent? Describe the process of commercial bleaching.

557. Name other uses of chlorine. Why was it especially adapted for use as a poisonous gas in the war? What compound was used in the gas masks to destroy the gas?

558. What is *a*) "Pyrene"?) *b*) "Carbona"?

559. When are elements said to be in the nascent state? How does their chemical activity differ in the nascent state from what it is in the usual molecular state? Illustrate.

560. What is the formula for hydrochloric acid? Give two other names for this acid.

561. Describe the laboratory preparation of hydrochloric acid as to *a)* materials used, with reasons for the use

of each, *b*) apparatus, *c*) method of collection, *d*) precautions to be observed. Write the equation.

562. Of what chemical industry is hydrochloric acid a by-product? Point out with illustrations the immense importance to chemical industries of by-products.

563. How may the qualitative composition of hydrochloric acid be shown? What is found to be the volume relation of the hydrogen and chlorine gases?

564. What is a gram molecule of HCl? Calculate the percentage composition of the acid.

565. Name four physical properties of HCl.

566. Write equations for the action of hydrochloric acid on *a*) zinc, *b*) magnesium, *c*) iron, *d*) sodium hydroxide, *e*) calcium oxide.

567. How does the action of HCl with metals differ from that of HNO_3 and H_2SO_4?

568. Give two illustrations of the action of hydrochloric acid as a reducing agent.

569. What is aqua regia? Write the equation for the reaction which this mixture produces. What is liberated? in what state? To what is the chemical activity of aqua regia due?

570. What is the name for the salts of hydrochloric acid? How may they be prepared? Name several that occur in nature. What three are insoluble?

571. What is the test for a chloride? Why is a confirmatory test necessary? What ion does the chloride test detect? Why will this test fail to give a result with $KClO_3$?

572. What are the names and formulae of the chlorine series of acids? What are the names of the corresponding sodium salts?

573. Give with formulae the names of a number of chlorine compounds and the uses of each.

574. Why should the discovery of the bleaching properties of chlorine have added an impetus to the manufacture of sulfuric acid?

BROMINE

575. In what compounds and in what localities does bromine occur in nature?
576. Describe the laboratory preparation of bromine. Give the reason for the use of each substance. Diagram the apparatus. Write the equation for the reaction.
577. Name four physical properties of bromine. In what liquid is it soluble? Compare these properties with those of chlorine.
578. State the chemical properties of bromine and compare them with those of chlorine.
579. Name uses of bromine compounds.
580. By what method would we expect to be able to prepare hydrobromic acid? What properties of hydrobromic and sulfuric acids respectively render this method impossible for the preparation of the pure acid? Write equations for the reactions.
581. Compare the action of concentrated sulfuric acid on sodium chloride and sodium bromide respectively. What do these chemical facts show concerning the relative reducing powers of hydrochloric and hydrobromic acids?
582. Describe a method for the preparation of pure hydrobromic acid.
583. What is the action of free chlorine upon solutions of bromides? What does this indicate concerning the relative stability of chlorides and bromides?
584. Describe the method of testing for a bromide.

IODINE

585. What are the natural sources of iodine?
586. Describe the laboratory preparation and collection of iodine. Write the equations for the reactions.
587. What is the commercial source of iodine?
588. Describe a method for the purification of iodine. Upon what property of the element does this method depend? What name is given to the process?

589. State the physical properties of iodine and compare them with those of chlorine and bromine respectively.
590. What is tincture of iodine? For what is it used?
591. In what other liquids is iodine readily soluble? What color does it give to them?
592. State the chemical properties of iodine and compare them with those of chlorine and bromine respectively.
593. What is the effect of both chlorine and bromine on solutions of iodides?
594. Which one of the halogens has the greatest heat of formation? Arrange them in the order of their decreasing chemical activity.
595. Describe *a*) two tests for iodine, *b*) the iodine test for starch.
596. Name uses of iodine and its compounds. What is iodoform? For what is it used?
597. Why cannot hydriodic acid be prepared by the action of sulfuric acid on an iodide? To what property of the acid is this due?
598. Describe a method for preparing hydriodic acid.
599. What products are formed by the addition of strong sulfuric acid to *a*) a chloride? *b*) a bromide? *c*) an iodide?
600. How do the above experiments indicate the relative reducing powers of the three halogen acids? Arrange these acids in the order of *a*) increasing reducing power, *b*) decreasing stability. How do their heats of formation compare?
601. How could you distinguish a chloride, a bromide, and an iodide?
602. Compare the elements of the halogen family as to *a*) physical state, *b*) color, *c*) density, *d*) chemical activity. State three points of resemblance between these elements.

PROBLEMS

603. Find the volume in cubic centimeters of hydrochloric acid solution of 1.1 specific gravity, and containing 20 per cent of actual acid by weight, that will be required to react with 50 grams of MnO_2.

604. What weight of silver chloride may be precipitated by silver nitrate from one kilogram of sea water containing 2.5 per cent of sodium chloride?

605. From 100 grams of hydrochloric acid what weight of chlorine can be obtained? What volume will this occupy at standard conditions? at 20° C. and 740 m.m.?

606. From 10 tons of sodium chloride what weight each of sodium sulfate and hydrochloric acid can be obtained?

607. How many grams of bromine can be obtained from 60 grams of potassium bromide?

608. Calculate the weight of manganese dioxide required to produce chlorine enough to fill a flask of 4 liters capacity when the barometer stands at 760 m.m. and the temperature is 0° C. What weight of manganese dioxide would be required if the flask were filled at 760 m.m. and 273° C.?

609. How many grams of hydrochloric acid gas can be obtained by heating ten grams of crystallized ferric chloride, $FeCl_3.6H_2O$, with concentrated sulfuric acid?

610. 71 grams of chlorine are to be united with hydrogen. What volume of hydrogen is required at 0° C. and 760 m.m., and what volume of hydrogen chloride results under the same conditions?

611. What weight of magnesium will be required to liberate 1 gram of hydrogen from hydrochloric acid? What relation is there between this number and the atomic weight of magnesium?

612. In what forms does carbon occur in the free state in nature?
613. Name examples of gaseous, liquid, and solid forms of combined carbon found in nature.
614. Give evidences of the fact that carbon is one of the most widely distributed elements.
615. Define allotropism. Distinguish between a crystalline substance and an amorphous substance.
616. Name and describe two crystalline forms of carbon. How may it be shown that each is pure carbon?
617. Describe the manufacture of artificial graphite by means of the electric furnace.
618. Name three uses of graphite and state the property upon which its value for each use depends.
619. Name four varieties of amorphous carbon.
620. How may pure carbon be prepared?
621. How was coal formed in nature?
622. From what variety of coal is coke manufactured? What is coke? Describe its manufacture. What are the by-products of this process? What name is given to the process? Why?
623. Name at least three important uses of coke? In what industry is it used in greatest quantity?
624. Compare the modern by-product coke ovens with the *bee-hive* ovens almost universally used in this country before the war. What tremendous national economy did they effect? Why was this industrial revolution a national necessity both for peace and war?
625. Describe the commercial preparation of charcoal. What are the by-products of the process? What are the uses of charcoal? What important use did the charcoal made from fruit pits serve during the war?
626. How is bone black prepared? What important use does it have in the refining of sugar?
627. Describe the preparation and state the uses of lampblack.

628. Name four physical and two chemical properties of carbon.

629. Describe some experiment to illustrate the reducing action of carbon. In what commercial process is this action of immense importance?

630. What is a carbide? Name two carbides of commercial importance.

631. Point out the uses of carbon in the following processes:—*a*) manufacture of acids and other chemicals, *b*) generation of electric power, *c*) metallurgy of iron and other metals, *d*) manufacture of electric light carbons, *e*) preparation of printer's ink and varnishes, *f*) purification of water, *g*) refining of sugar, *h*) preparation of paints, lubricants, and stove polish. In each case what variety of carbon is used and what property adapts it to this particular use?

632. With what other elements does carbon unite to form a large number of compounds?

633. What is a hydrocarbon? Where do hydrocarbons occur in nature?

634. Give the chemical name and formula of marsh gas. What is the valence of carbon? Write the graphic formula for marsh gas.

635. Where is marsh gas found in nature? Account for its formation. Of what is it a principal constituent?

636. What are the physical and chemical properties of methane?

637. What is *"fire damp"?* Why is it dangerous? Describe the Davy safety lamp and explain why it prevents explosions of fire damp.

638. Give the formula of acetylene. Describe its preparation and write the equation for the reaction involved.

639. Describe the construction of a simple acetylene generator.

640. What temperature does the oxyacetylene torch give? Point out its very great importance in the metal industries.

641. Name one other important use of acetylene.

642. What are the products of the complete combustion of *a*) methane? acetylene? Write equations for the reactions.
643. Give the names and formulae of the two oxides of carbon.
644. Where does carbon dioxide occur in nature? Of what natural processes is it a product?
645. Describe the laboratory preparation of carbon dioxide as to *a*) apparatus, *b*) materials used, *c*) method of collecting the gas. Write the equations for the reactions that occur.
646. In the above process what compound is first formed? Into what does it break down? Why may hydrochloric acid be used in this case?
647. Name the physical properties of carbon dioxide. Describe an experiment to show that it is heavier than air.
648. Name the chemical properties of carbon dioxide.
649. Name one natural and two commercial uses of carbon dioxide.
650. Make a diagram to show the construction of a fire extinguisher. Explain its operation.
651. Compare carbon dioxide, "Carbona," "Pyrene," and "Foamite" as to their effectiveness in extinguishing fire.
652. What is the formula of carbonic acid? its anhydride? its radical? the valence of the radical? the name of its salts?
653. From what two standpoints is carbonic acid a weak acid?
654. Write equations for the reactions that occur when carbon dioxide is passed into solutions of the following bases:—NaOH, KOH, $Ca(OH)_2$.
655. Name three carbonates of commercial importance. What ones are insoluble?
656. How may an insoluble carbonate be precipitated? Illustrate by writing equations for the precipitation of calcium, magnesium, and barium carbonates.

657. What is the test for CO_2? for a carbonate? How may it be shown that CO_2 is a product of *a*) respiration? *b*) combustion? How may its presence in the air be shown?

658. What is the first result of passing CO_2 into lime water? the second on continued passage of the gas? Explain. Write the equations.

659. What is the effect of subjecting a carbonate to strong heat? Write equations for the reactions that result from heating calcium carbonate and magnesium carbonate.

660. How could you show the presence of powdered charcoal in an impure sample of manganese dioxide? Upon what property of carbon does your method depend?

661. Describe two methods for the preparation of carbon monoxide.

662. Name three physical and two chemical properties of carbon monoxide.

663. Of what commercial product is carbon monoxide a principal constituent? What are its uses?

664. Account for the production of carbon monoxide when an automobile engine is run for some time in a closed garage.

665. What is the formula of hydrocyanic acid? What is its common name? What is the name of its salts? What two are best known? What is their most important property?

666. Name two important commercial uses of potassium cyanide. Describe the cyanide process for the extraction of gold.

667. Explain the *hydrolysis* action of water by which solutions of potassium cyanide are rendered alkaline.

668. Show also how hydrolysis action is involved in a solution of sodium carbonate.

669. How could you distinguish between *a*) carbon dioxide and carbon monoxide? *b*) hydrogen and methane? *c*) methane and carbon monoxide?

670. How could you distinguish between a carbonate and a sulfite?

671. Find the weight of each of the products of combustion when 78 grams of acetylene burn.

672. A paraffin candle (C 82%, H 18%) weighs 100 grams. Find the weights of the products formed by the complete combustion of the candle.

673. What weight of hydrochloric acid is necessary to neutralize completely 5 grams of $Na_2CO_3.10H_2O$? What volume of gas measured at 15° C. and 750 m.m. is produced?

674. What weight, and what volume at 0° C. and 760 m.m., of carbon dioxide can be obtained by treating an excess of sodium carbonate with 490 grams of sulfuric acid containing 20 per cent of HSO_4?

FLAMES AND ILLUMINANTS

675. Give illustrations of combustion in which *a*) a flame is produced, *b*) no flame is produced. What is necessary for a flame? Why does a candle burn with a flame? Why does petroleum?

676. Which of two combining gases is regarded as the supporter of combustion? Describe an experiment for the burning of air in an atmosphere of illuminating gas.

677. Describe the construction of the Bunsen burner.

678. Of how many cones does a Bunsen burner flame consist? Of what does the innermost cone consist? What is the condition of the gas in this cone at *a*) bottom? *b*) top? Where is the hottest part of the flame? Why?

679. What part of the Bunsen flame is called *a*) the oxidizing flame? *b*) the reducing flame? Explain why. What uses are made of these flames?

680. Upon what does the luminosity of a flame depend? How may it be shown that particles of carbon exist in a luminous flame?

681. Account for the immediate condensation of moisture on the outside of a dry beaker of cold water when placed over a Bunsen flame.

682. What is the cause of the striking back of a Bunsen flame or the flame of a gas stove? How may this be prevented?

683. Name four important illuminating and fuel gases.

684. From what kind of coal is *coal gas* manufactured? What elements are found in this coal? Into what forms are they converted by destructive distillation? Which element is objectionable? Why?

685. Describe a plant for the manufacture of coal gas showing the construction and purpose of each of the following parts:—*a*) gas retorts, *b*) hydraulic main, *c*) scrubber, *d*) purifier, *e*) gas holder.

686. From what impurities must the gas be freed? How is this accomplished?

687. What are the by-products of coal gas manufacture? For what are they used? Point out the very great importance of these products in making munitions of war.

688. How is the ammonia gas liberated from the ammoniacal liquor of the gasworks? Of what does this liquor consist? To what uses is the ammonia gas put?

689. Of what does *water gas* consist? Describe the classroom preparation of the gas. Write the equation for the chemical reaction.

690. Describe the construction and operation of a water gas plant explaining the purpose of each of the following parts:—*a*) generator, *b*) carburetor, *c*) superheater.

691. Why nust water gas be enriched for illuminating purposes? What is meant by the "cracking" of petroleum which occurs in the enriching process?

692. What is the chief objection to the use of water gas for household purposes?
693. What is producer gas? How is it manufactured? Write the equations for the reactions that occur. For what important industrial purposes is it used?
694. State, in order of abundance, the principal constituents of *a*) coal gas, *b*) water gas, *c*) natural gas.
695. State the relative importance of the constituents of coal gas in the production of *a*) light, *b*) heat.
696. What are the objections to heating rooms with oil or gas stoves which have no flues?
697. In what unit is the heat value of coal and gas measured? How are these values determined?
698. To what causes is the great heat loss in the industrial combustion of coal due? Discuss the automatic stoker as a means of preventing a large part of this loss, as well as abating the smoke nuisance.
699. Describe the construction and operation of *a*) the arc type of electric furnace, *b*) the resistance type.
700. Name important industries that make use of electric furnaces.
701. Describe the construction of the Welsbach mantle. What materials are used? Upon what does its efficiency depend?
702. What is the cause of the blue flame often seen playing over the surface of a coal fire? Describe the combustion taking place, in a freshly built furnace fire, from the bottom of the fire box to the top. Write the equations for the chemical reactions occurring in the various stages of the combustion.

GAY-LUSSAC'S LAW OF GAS VOLUMES

703. State Gay-Lussac's law. Upon what does the truth of this law rest?
704. What does the following equation indicate concerning

the volumes of the respective gases taking part in the reaction?

$$CH_4 + 2O_2 = CO_2 + 2H_2O.$$

NOTE:—It must be carefully observed that in writing a gas volume equation an elementary gas, as oxygen or hydrogen, must be represented with two atoms to the molecule. For instance, in the above equation, oxygen must be $2O_2$ and not 4O. The reason why the coefficients of a molecular equation represent the relative volumes of the respective gases taking part in the reaction will become clear from a consideration of Avogadro's hypothesis.

705. State Avogadro's hypothesis.

706. Experiment shows that 1 liter of hydrogen unites with 1 liter of chlorine to form 2 liters of hydrochloric acid gas, all the volumes being measured under the same conditions of temperature and pressure. With these experimental facts together with Avogadro's hypothesis prove that *a*) the molcule of hydrogen contains 2 atoms, *b*) the molecule of chlorine contains 2 atoms.

707. Making use of Avogadro's hypothesis show why the coefficients in the molecular equation for a gas reaction must represent the relative volumes of the gases taking part.

708. Write the volume equation for the combustion of each of the following gases:—CO, H_2, C_2H_2, CH_4, H_2S, CH_3OH.

709. What volume of carbon dioxide will be formed in the combustion of 10 cubic feet of acetylene? How many cubic feet of oxygen will be required? How many cubic feet of air?

710. What volume of oxygen will be required to burn 1,000 c.c. of CO? What will be the volume of the product?

711. How many liters of air are needed for the complete combustion of 50 liters of methane?

712. Write the volume equation for the complete combustion of carbon disulfide vapor.

713. A volume of 100 c.c. of dry ammonia is decomposed by electricity. Name the gases formed and give the volume of each.

714. What chemical change is indicated by the equation:—

$$H_2 + Cl_2 = 2HCl?$$

State regarding the equation *a*) the number of atoms in each reacting molecule and in the product, *b*) the number of molecules, *c*) the relative volumes, *d*) the number of parts by weight of each substance involved.

MOLECULAR AND ATOMIC WEIGHTS

715. What is meant by the term *chemical equivalent,* or *combining weight,* of an element? Describe the laboratory method of determining the equivalent of magnesium.

716. State the equivalents of oxygen, chlorine, sulfur, nitrogen, sodium, magnesium, and zinc. In every case how is the equivalent determined?

717. What relation exists between these numbers and the atomic weights of the respective elements?

718. In case an element forms no compound with hydrogen how may its equivalent be obtained?

719. What is meant by the molecular weight of a gas? the vapor density of a gas? What relation exists between the molecular weight of a gas and its vapor density?

720. Arrange the following gases in the order of increasing density:—CO_2, CH_4, N_2O, CO, NH_3, O_3.

721. Making use of Avogadro's hypothesis and the fact that there are two atoms in the molecule of an elementary gas, prove that the vapor density of a gas referred to hydrogen is one-half its molecular weight.

722. What is a gram molecule of a gas? What relation

exists between the gram molecule of a gas and the volume that it occupies at standard conditions?

723. What is the *gram-molecular volume* of any gas?

724. The weight of 22.4 liters of air at standard conditions is 28.9 grams. How, then, can you calculate the density of a gas referred to air?

725. Find the densities referred both to hydrogen and air of the following gases:—oxygen, ozone, ammonia, hydrogen sulfide, acetylene, marsh gas, carbon dioxide, nitric oxide.

726. The density of a certain gas referred to hydrogen is 22. Find its molecular weight and its density referred to air.

727. The densities referred to air of several gases are respectively 1.179, 2.22, 2.74, and 4.70. Find their molecular weights and vapor densities referred to hydrogen.

728. From a knowledge of the gram-molecular volume of any gas and its molecular weight how can you calculate the weight of 1 liter of it?

729. The weights of 1 liter each of several gases are respectively 1.16 g., 0.7617 g., 1.964 g., 1.25 g., 1.43 g., 0.09 g., and 0.7157 g. Calculate their molecular weights and their densities referred to hydrogen.

730. Calculate the weight in grams of 1 liter of each of the following gases:—chlorine, nitric oxide, sulfur dioxide, oxygen, nitrogen, carbon dioxide, and ozone.

731. How many grams of hydrogen sulfide can be obtained by the action of an excess of sulfuric acid on 44 g. of ferrous sulfide? Tell by inspection the number of liters of the gas at standard conditions.

732. How many liters of oxygen measured at standard conditions can be obtained by the decomposition of 245 grams of $KClO_3$?

733. State how the molecular weight of any gaseous compound or element may be experimentally determined.

734. Explain how the following data leads to a knowledge of the atomic weight of oxygen:—

Name of Compound	*Molecular Weight (Weight 22.4 l)*	*Percentage of Oxygen by Experiment*	*Part of Molecular Weight Due to Oxygen*
Water	18	88.88	16
Carbon monoxide	28	57.14	16
Nitric oxide	30	53.33	16
Carbon dioxide	44	72.72	32
Sulfur dioxide	64	50.00	32
Sulfur trioxide	80	60.00	48

735. An experiment showed that, when 2.16 g. of silver were treated with chlorine, 2.87 g. of silver chloride were formed. Calculate from this result the atomic weight of silver. (Atomic weight of chlorine is 35.5.)

736. It is found that 2 g. of sulfur combine with 3.5 g. of iron to form iron sulfide, FeS. Calculate the atomic weight of iron. (Atomic weight of sulfur is 32.)

737. If 6.34 g. of iron form 9.06 g. of Fe_2O_3 what is the atomic weight of iron?

738. Of 111.45 g. of lead oxide, PbO, 8 g. are oxygen. Find the atomic weight of lead.

739. One gram of pure iron forms 1.43 g. of an oxide. Find the chemical equivalent of iron in this compound.

740. One gram of sulfur forms 2.5 g. of an oxide. Find the chemical equivalent of sulfur for this compound.

741. If 0.05 g. of magnesium liberates 0.00411 g. of hydrogen from hydrochloric acid, calculate the chemical equivalent of magnesium.

CALCULATION OF FORMULAE

NOTE:—To calculate the formula of a compound where the data given leads to a knowledge of its molecular weight, the method is as follows:—Find the molecular weight.

Then from the percentage composition find the part of the molecular weight due to each element and finally divide these results by the respective atomic weights of the elements. This last set of numbers will be the number of atoms of the respective elements in the compound.

742. Calculate the formula of the gas, a liter of which at standard conditions weighs 1.17 g. and whose composition by weight is carbon 92.31%, hydrogen 7.69%.

743. The percentage composition of a compound is as follows:—oxygen, 49.86%; hydrogen, 12.53%; carbon, 37.61%. One liter of its vapor weighs 1.4339 g. Find its formula.

744. The density referred to air of a gas is 1.179 and its composition, sulfur 94.11%; hydrogen 5.89%. Find its formula.

745. The vapor density referred to hydrogen of a gas is 32 and its composition, sulfur 50.05%; oxygen 49.95%. Find the formula.

746. The weight of 1 liter of a gas is 0.7157 g. and its composition is carbon 75%; hydrogen 25%. Calculate the formula.

747. What is the formula of a compound the vapor density of which referred to hydrogen is 13.64 and its composition:—iodine 96.70%, hydrogen 0.25%, and carbon 3.05%?

748. The vapor density referred to air of acetic acid is 2.078 and its composition is carbon 40%, oxygen 53.33%, and hydrogen 6.67%. What is its formula?

749. The vapor density referred to hydrogen of a compound is 23 and its composition is carbon 52.17%, oxygen 34.80%, hydrogen 13.03%. Calculate its formula.

NOTE:—To find the simplest formula of a compound from a knowledge of its percentage composition only, the method is as follows:—Divide the percentage of each element by its atomic weight. This set of quotients will be proportional to the actual numbers of atoms of the respective elements in the compound. Therefore divide these

quotients by the smallest one of them and the results will be the numbers of atoms of the respective elements in the simplest formula.

750. Calculate the simplest formula of a compound containing 92.59% mercury and 7.41% oxygen.

751. What is the simplest formula of a substance having the following composition:—calcium 29.49%, sulfur 23.59%, and oxygen 46.92%?

752. A compound has the following composition:—carbon 54.67%, hydrogen 9.11%, oxygen 36.22%. Find the simplest formula.

753. Calculate the simplest formulae of compounds having the following compositions:—

Ba 58.80%	S 13.75%	O 27.45%
Mn 63.22%	O 36.78%	
Ca 50.12%	C 12.04%	O 47.84%
Pb 62.45%	N 8.68%	O 28.85%
Pb 68.30%	S 10.55%	O 21.15%

THE PHOSPHORUS FAMILY

754. Name the members of the phosphorus family and the symbol of each.

755. What are the valences of these elements? Illustrate by writing the formulae for their oxides and chlorides.

756. With reference to each element state whether it is acid forming or base forming.

757. Point out the gradation of properties exhibited by these elements with their increasing atomic weights.

758. Where and in what compounds does phosphorus occur in nature? Why is it not found in the free state?

759. Describe briefly the method of manufacturing phosphorus.

760. What two allotropic forms of phosphorus are known?

761. Name four physical properties of yellow, or white, phosphorus.

762. What is the most striking chemical property of yellow phosphorus? With what other elements does it readily combine? How must it be kept? Why?

763. What precautions must be observed in handling yellow phosphorus? Why is a solution of potassium permanganate the most efficient remedy for immediate application to a phosphorus burn?

764. Which is the more stable form of phosphorus? How is red phosphorus prepared? In what respects does it differ from yellow phosphorus?

765. Describe the preparation of common matches. What properties of the substances used adapt them to their specific purposes? Describe the chemical changes that occur in the ignition of a match.

766. Describe the preparation of safety matches as to *a*) materials used on the match head, *b*) materials used on the side of the box, *c*) the chemical changes that occur in striking the match.

767. Give the names and formulae of the two oxides of phosphorus. Of what acids are they the anhydrides? How is each prepared? Name an important property of the higher oxide and a practical use to which it is put. Where in the laboratory has this oxide been prepared? What is its appearance?

768. Why is phosphoric acid a *tribasic* acid? Illustrate your answer by writing the formulae for the three sodium salts of this acid. What are their names?

769. To what important commercial use is the normal calcium phosphate of nature put? What treatment must it receive before it becomes available for this purpose? Write the equation for the reaction that takes place in this process. Why is this treatment necessary? What is the name of the product?

770. Where is phosphate rock found in this country?

ARSENIC

771. In what compounds does arsenic occur in nature? How is it obtained in the free state?

772. State the physical properties of arsenic. Describe its chemical behavior.
773. What is the chief use of the element, arsenic? Describe the process of making lead shot. What properties does arsenic impart?
774. What is arsine and how is it prepared? What are its properties?
775. Describe Marsh's test for arsenic. What precautions must be observed? With what other element may it be confused? How may it be distinguished?
776. What is the most important oxide of arsenic? What are its uses?
777. Name a number of arsenic compounds used in agriculture as insecticides. What is Paris green?
778. What is the most efficient antidote for arsenic poisoning?

ANTIMONY

779. In what compound chiefly does antimony occur in nature? In the metallurgy of what other metal is it frequently obtained as a by-product?
780. State *a*) the physical properties of antimony, *b*) the chemical properties.
781. Under what circumstances does antimony act as a metal? a non-metal? Define metalloid.
782. What is an alloy? How do the properties of an alloy differ from those of the constituent metals?
783. What properties does antimony impart to its alloys? Name two alloys of antimony and the constituents of each.
784. Tell something of the very great importance of alloys in the industrial world.

BISMUTH

785. State the physical properties of bismuth. Upon what chemical property is its classification as a metal based?

786. What is "bismuth subnitrate" and for what is it used?
787. Name one important alloy of bismuth and its constituent metals. To what uses are the low melting-point alloys of bismuth put?

HYDROLYSIS

788. What is meant by the hydrolysis action which many salts undergo?
789. Upon what fact of water does this action depend?
790. What kind of a reaction will sodium carbonate solution give with litmus? Explain. Write the equation.
791. What kind of a reaction will copper sulfate solution give with litmus? Explain. Write the equation.
792. Why will sodium chloride solution give neither an acid nor a basic reaction?
793. Does the term "normal salt" always necessarily mean a perfectly neutral salt? Under what circumstances will hydrolysis occur?
794. Point out important applications of hydrolysis action.

SILICON

795. In what compounds and where does silicon occur in nature?
796. What other element in the periodic table does silicon resemble and in what respects?
797. What is a silicide? a carbide? carborundum?
798. Describe the manufacture of carborundum as carried out at Niagara Falls. Name important uses of this artificial abrasive.
799. In what crystal form does silicon dioxide, or silica, crystallize in nature? Name six of its varieties. What are its properties?
800. Name four important uses of sand.
801. Write equations for the reactions that occur when silicon dioxide is fused with *a*) sodium carbonate,

b) sodium sulfate, *c*) lime, i.e., calcium oxide, *d*) potassium carbonate.

802. Name with formula the simplest of the silicon acids. What is the name of its salts? What is *a*) clay? *b*) feldspar? *c*) kaolin?

803. Name the most important compounds of which glass consists. What is the physical nature of glass? How would you define glass?

804. Describe the manufacture of glass as to *a*) the furnace, *b)* melting pots, *c)* raw materials, *d)* the chemical changes that occur, *e)* the blowing of the glass, *f)* the annealing.

805. Name the three principal varieties of glass. What are the constituents of each? How do the three varieties differ in properties? What are the uses of each?

806. Write equations for the reactions involved in the making of each of the three kinds of glass.

807. How are the various colors given to glass? In making colorless glass how may the yellow or green color due to iron be neutralized?

808. What is waterglass? How is it made? What are its uses?

809. What properties does "silica ware" possess which especially adapt it for laboratory use?

810. Describe how *a*) plate glass is made, *b*) bottles are blown, *c*) window glass is blown and shaped.

811. From where did this country formerly obtain practically all of its chemical and optical glass? What can be said concerning the quality and quantity of these kinds of glass now manufactured in this country? To what is this condition due?

812. What kind of a reaction with litmus would a solution of sodium silicate be likely to give? Why?

BORON

813. What are the two most important compounds of boron? Give their formulae.
814. What are the uses of boric acid? Describe a method of testing for it.
815. What is a flux? How is borax used as a flux?
816. Describe the borax bead test for metals.
817. Name other uses of borax.
818. Why is a solution of borax alkaline?

THE METALS

819. Define *a*) metal, *b*) non-metal, *c*) metalloid.
820. Name three metals that are found in the free state. What are the most important compounds in which metals occur?
821. Distinguish between a mineral and an ore.
822. Define metallurgy. Name and briefly describe, with an illustration of each, three general methods of extracting a metal from its ore.
823. Name and describe with illustrations and equations each of five general methods of preparing metallic compounds.
824. Name four metals that will be precipitated from solutions of their salts by *a*) zinc, *b*) iron, *c*) lead, *d*) copper.
825. How may pure silver be obtained from a silver coin?
826. Write equations representing four different ways of preparing copper nitrate.
827. State the solubilities in water of the metallic *a*) hydroxides, *b*) nitrates, *c*) chlorides, *d*) sulfates, *e*) carbonates.
828. According to the ionic theory what takes place when *a*) copper sulfate is dissolved in water? *b*) metallic zinc is added to the resulting solution?

829. Name the alkali metals. What two are most important? How do they occur in nature? What is the general method for their preparation?
830. State the properties which these metals have in common. What can be said of the solubility of alkali compounds? Why are these elements called metals?

SODIUM

831. What is the most abundant compound of sodium in nature. Name other natural compounds of sodium.
832. Who discovered sodium and by what method?
833. Diagram the apparatus for the commercial preparation of sodium and describe the process.
834. State the physical and chemical properties of sodium.
835. What is the formula of sodium peroxide? What reaction occurs between sodium peroxide and water? What laboratory use is made of this reaction?
836. What is caustic soda? Diagram the electrolytic cell and describe the process for making it by the electrolysis of brine.
837. State the properties of sodium hydroxide and name three important uses.
838. What chemical changes will occur if solid sodium hydroxide is exposed to the air for a considerable period of time? What is lye?
839. What are the sources of sodium chloride? Name several localities in which it is found. Describe the extraction of the salt from its natural deposits. Why is the salt usually deliquescent?
840. Name three important uses of sodium chloride aside from those of chemical industry. Why is this salt so important chemically? Name five chemical substances that directly or indirectly are dependent upon this compound for their manufacture.
841. What is Glauber's salt? What is "hypo"? What important uses does the latter compound have?

842. What is sal soda? Write the formula of the crystallized salt.
843. Describe fully with all equations the LeBlanc process for the manufacture of soda. What valuable by-product has enabled this process to compete with the more modern Solvay process?
844. Describe with equations for the reactions the Solvay process. Show how by-products are utilized and the ammonia recovered from the "mother liquors."
845. In the Solvay process how is the bicarbonate that is first formed converted into the normal salt? How may the reverse reaction be brought about? Write the equations for the reactions.
846. What are several important uses of sodium carbonate? What is the effect of exposing the crystals of the salt to the air? What name is given to this change? What is anhydrous sodium carbonate?
847. What is the reaction with litmus of a solution of *a*) sodium carbonate? *b*) sodium bicarbonate? Explain. How could you distinguish the two salts in the laboratory?
848. What is *a*) baking soda? *b*) baking powder? For what are they used and when should one be used rather than the other? Why does baking powder deteriorate upon standing in an uncovered box?
849. Should baking powder be mixed with the flour before or after the addition of the liquid? Explain.
850. Name three substances that may be used as the acid constituent of baking powder.
851. What is Chili saltpeter? How is it obtained from its deposits? What are its important uses? What industrial process is rendering the world somewhat less dependent upon Chili saltpeter?
852. How may sodium in its compounds be tested for? How would you identify sodium sulfate? sodium chloride? sodium iodide?
853. Describe a laboratory method of preparing chemically

pure sodium chloride from common salt. What principle is illustrated?

854. Name four compounds of sodium employed in the household.

855. How much soda can be manufactured from 5 kg. of salt by the Solvay process? What weight of gaseous ammonia will be required?

856. What weight of sodium hydroxide can be obtained from 1 ton of sodium chloride?

857. How much nitric acid can be obtained from 5 tons of crude Chili saltpeter containing 60 per cent of the pure salt?

POTASSIUM

858. In what rocks and minerals does potassium occur? How do you account for its presence in soils?

859. Describe the immense deposits of natural potash compounds at Stassfurt, Germany. What compounds of potassium are found there? In what minerals do they occur?

860. Point out the very great importance of these deposits to agriculture and industry.

861. What other sources of potassium compounds were developed during the war when the world was cut off from the German supply? To what extent did the output of these sources meet the needs of industry?

862. By what processes are the potassium compounds extracted from the Stassfurt deposits?

863. In what compounds is potassium used as a fertilizer?

864. What three elements are essential constituents of commercial fertilizers? In what compounds are they used as fertilizers?

865. Name five compounds of potassium and one or more important uses of each.

866. Point out the use of potassium compounds in the preparation of the following:—*a*) glass, *b*) soap, *c*) gunpowder, *d*) baking powder, *e*) matches, *f*) in-

secticides, *g*) fireworks, *h*) oxygen, *i*) meat preservatives, *j*) drugs, *k*) photographic preparations.

867. What is saltpeter? Describe its preparation from Chili saltpeter and potassium chloride. Write the equation. Since all four factors of the reaction are soluble explain how the saltpeter may be made to crystallize out.

868. What is the chief chemical property of saltpeter? What are its uses?

869. What are the ingredients of ordinary gunpowder? What is the purpose of each ingredient? What are the products of its ignition? Why is potassium nitrate better than sodium nitrate for gunpowder?

870. What is "potash"? What is the significance of the term? Give two reasons for the use of wood ashes as a fertilizer.

871. What is cream of tartar? How is it obtained? For what is it used? Why?

872. Describe the flame test for potassium. How may potassium be recognized in the presence of sodium?

873. How would you identify *a*) potassium chloride? *b*) potassium bromide? *c*) potassium iodide?

874. Name one or more important uses of each of the following:—potassium chlorate, potassium bromide, potassium iodide, potassium hydroxide.

875. Why are solutions of potassium carbonate alkaline?

876. Why are sodium compounds more extensively used than potassium compounds?

877. Why will not $KClO_3$ give the test for a chloride?

878. What is the test for a nitrate? How could you identify potassium nitrate? distinguish it from sodium nitrate?

879. What volume of oxygen measured at 20° C. and 720 m.m. can be obtained from the decomposition of 245 g. of $KClO_3$?

880. From 500 pounds of potassium chloride how many pounds of saltpeter can be obtained?

881. Describe the flame test for lithium.

882. Describe the construction of the spectroscope. Discuss its use in *a*) chemical analysis, *b*) the detection of the elements present in distant stars.

AMMONIUM COMPOUNDS

883. What is the ammonium radical? its valence?
884. What is sal ammoniac? What is the effect of heating it? How may it be purified? What are its uses?
885. How may an ammonium salt be identified? How could you distinguish between sodium chloride and ammonium chloride?
886. What important agricultural use does ammonium sulfate have? How is it prepared commercially?
887. Name two uses of ammonium nitrate. What are "smelling salts"?
888. What important anaesthetic is prepared from ammonium nitrate? Write the equation for the reaction.
889. What weight of ammonia gas can be obtained from 264 grams of ammonium sulfate? What volume will this occupy at standard conditions?

ALKALINE-EARTH METALS

890. What are the members of the alkaline-earth family? In what compounds do they occur in nature? What is the valence of each?
891. Discuss the solubilities of the sulfates, carbonates, and hydroxides of these metals. Compare the solubilities of compounds of the alkaline-earth metals with the corresponding compounds of the alkali metals.
892. Name with formulae four natural compounds of calcium.
893. What is quicklime? What is the effect of the oxyhydrogen flame upon it? Describe its action with water and state the name given to this action. What is the action of air upon quicklime? Write equations for these reactions.

894. From what is lime prepared? How? Describe the construction and operation of a modern limekiln.

895. What is *a)* slaked lime? *b)* limewater? milk of lime? whitewash?

896. Of what does mortar consist? Explain the "setting" of mortar. Write the equation for the chemical reaction involved. What are the functions of sand in mortar?

897. Describe the processes and write the equations representing the changes that take place from the time limestone leaves the quarry until the mortar made therefrom hardens by exposure to the air.

898. How would you distinguish by means of a chemical test between old mortar and fresh mortar?

899. How does plaster differ from mortar? How does it set? Of what do some forms of modern plaster consist?

900. What is Portland cement? From what raw materials is it made? Describe its manufacture. Why is it called hydraulic cement?

901. What are the uses of cement? What is *a*) concrete? *b*) reinforced concrete? Point out the very great importance of concrete in structural work.

902. Coke, lime, and sulfuric acid are the most important raw materials of chemical industries. Point out the use of lime in each of the following processes:— *a*) Solvay process, *b*) purification of coal gas, *c*) recovery of ammonia from the ammoniacal liquor of the gasworks, *d)* making of mortar and cement, *e*) manufacture of glass, *f*) preparation of bleaching powder, *g*) sugar refining, *h*) metallurgy of iron, *i*) removal of temporary hardness from water, *j*) tanning of hides.

903. In what forms does calcium carbonate crystallize? Name one important crystalline form. How may a geologist distinguish between *a*) limestone and marble? *b*) limestone and sandstone?

904. What is natural chalk? precipitated chalk? Why is

the latter used in tooth pastes? What is whiting? putty?

905. What kind of a salt is anhydrous calcium chloride? For what is it used?

906. What is the formula of bleaching powder? What is its chemical name? Describe its manufacture. Write the equation for the reaction involved.

907. What are the uses of bleaching powder? What is the action on bleaching powder of *a*) sulfuric acid? *b*) air?

908. What is fluorspar? State its uses.

909. What is the chemical name and formula of gypsum? Where does it occur?

910. What is plaster of Paris? How is it made? What causes it to set? How does the setting of plaster of Paris differ from that of mortar? State its uses and point out its numerous applications in the preparation of building materials.

911. What was the original significance of the terms "hard" and "soft" as applied to water?

912. What are the two kinds of hardness?

913. To the presence of what compound in water is temporary hardness due? How do you account for the presence of this compound in natural waters? Into what two ions does this compound dissociate?

914. Describe two methods for removing temporary hardness from water. What ion is removed in each case? How? Write the equations for the reactions that occur.

915. To the presence of what compounds in water is permanent hardness due? Into what ions do they dissociate? Why is this hardness called "permanent"?

916. How may permanent hardness be removed? Write the equation for the reaction. What ion is removed?

917. What ion is common to both kinds of hardness? To the presence of what, then, is both kinds of hardness really due?

918. What is the action of soap solution on either kind of hard water? What kind of soap results from this action? Before the cleansing action of soap becomes effective what must happen to the calcium and magnesium salts in solution? Why is the use of hard water uneconomical?

919. What is a standard soap solution? By means of it how may the relative degrees of hardness in different samples of water be determined?

920. How may it be determined whether water *a*) is hard? *b*) has temporary hardness only? *c*) has permanent hardness only? *d*) has both kinds of hardness?

921. Discuss the use on a large scale of such modern water softeners as "permutit," "refinite," and "softite." What is their chemical nature? How do they soften the water? How are they regenerated? What principle is involved in these changes?

922. Name several industries that use large quantities of soft water.

923. Discuss boiler scale as to *a*) its causes, *b*) its harmful effects, *c*) its remedies.

924. Describe the manufacture of calcium carbide. For what is it used? Write the equations for the reactions involved in its preparation.

925. Describe the preparation of calcium cyanamide. Write the equations for the reactions that occur. Name two important commercial uses of this product.

926. What volume of air will be required to burn 50 liters of acetylene?

927. For what is calcium phosphate important?

928. What color is imparted to the flame by *a*) calcium compounds? *b*) strontium compounds? *c*) barium compounds?

929. For what are the nitrates of strontium and barium used? Why?

930. What is the test for the sulfate radical?

931. What weights of lime and carbon dioxide can be obtained by the decomposition of 10 tons of lime-

stone? What weight of water will be required to slake the lime?

MAGNESIUM

932. In what compounds does magnesium occur in nature?
933. State the physical and chemical properties of magnesium. Name two important uses of the metal.
934. What is magnesia? How is it obtained? What are its properties and uses?
935. What is milk of magnesia? For what is it used?
936. What is dolomite? What important use does it have in the metallurgy of iron?
937. Give the formula, chemical name, and uses of Epsom salt?
938. State the general composition and the uses of meerschaum, talc, soapstone, and asbestos.

ZINC AND CADMIUM

939. Name with formulae the two most important ores of zinc.
940. Starting with the sulfide describe the metallurgy of zinc. Why must retorts be used? Diagram the retort and condensing chamber. Name and account for the impurities present in zinc.
941. Name the physical properties of zinc.
942. Discuss the chemical properties of zinc with respect to *a*) its action with moist air, *b*) its action with acids both when the metal is pure and when impure, *c*) its action with sodium and potassium hydroxides together with equations for the reactions that occur.
943. What is galvanized iron? How is the galvanizing done? Give the reasons for the efficiency of zinc as a protective coating for iron. Compare it with tin in this respect.
944. Name *a*) two laboratory uses of zinc, *b*) two alloys of zinc with the constituents of each.

945. What is zinc white? How is it prepared? Discuss its useful qualities as a paint pigment. Name another use.
946. What is white vitriol? What are the properties and uses of zinc chloride? What is lithophone?
947. Name a use of *a*) the metal cadmium, *b*) cadmium sulfide.

ALUMINUM

948. Name four minerals, together with the composition of each in which aluminum occurs in nature. What percentage of the earth's crust does it compose? What is the valence of aluminum?
949. Describe with aid of a diagram the electrolytic process for the manufacture of aluminum. What chemist discovered this process?
950. Name four physical properties of aluminum.
951. State the action of aluminum with respect to *a*) moist air, *b*) hydrochloric, nitric, and sulfuric acids, *c*) sodium and potassium hydroxides with equations for the reactions, *d*) salt solutions.
952. Name important uses of aluminum and state the properties which especially adapt it to each use.
953. Name two alloys of aluminum and the constituents of each.
954. Of what does *thermit* consist? Write the equation for the reaction that occurs when it is ignited. What does this ignition liberate?
955. Discuss the importance of the thermit process in its relation to *a*) welding, *b*) metallurgy.
956. What is *a*) an endothermic reaction? *b*) an exothermic reaction? Give examples of each.
957. Name three natural varieties of aluminum oxide. What are their properties and uses?
958. What is "alundum"? What are its properties and uses?

959. What is the formula of aluminum hydroxide? How may it be precipitated? What are its properties?
960. Discuss the use of aluminum hydroxide for the clarification of water and the removal of soluble coloring matter.
961. What is a mordant? Show how aluminum compounds may be used as mordants. Name other compounds that are also used as mordants.
962. What are dye "lakes"? How are they formed? Of what importance are they in the preparation of pigments?
963. Discuss both *acid dyes* and *basic dyes* in relation to their use with cotton, silk, and woolen fabrics. In what cases may these fabrics be dyed directly and in what cases must a mordant be employed?
964. What is a double salt? Give the formula of potassium alum? How may it be prepared? Name other alums.
965. What are the purpose and chemical action of alum in baking powders?
966. What is *a*) feldspar? *b*) mica? *c*) kaolin?

CERAMIC INDUSTRIES

967. What are the products of ceramic industries. What are the raw materials of their manufacture?
968. For what is the purest kaolin used? With what other substances must it be mixed? What is the purpose of each ingredient?
969. Describe the manufacture of fine porcelain as to *a*) preparation and mixing of the raw materials, *b*) shaping and drying of the ware, *c*) firing, *d*) glazing, *e*) ornamentation.
970. What compounds are used for glazing?
971. What is common crockery?
972. Describe the manufacture of brick. To what is their red color due?
973. What are fire bricks?

974. Give evidences of the wide distribution of iron in nature.

975. Why are we sometimes said to live in "the age of steel and concrete"? Why was steel of paramount importance in the Great War?

976. Name with formulae four ores of iron.

977. Of what does iron ore as it comes from the mines consist? From what must the ore be separated in the blast furnace? In either of what two physical states must all the materials that enter the blast furnace leave it?

978. What are the functions of each of the following materials used in the smelting of iron ore:—coke? hot air? flux?

979. Of what materials does the flux consist? How do these materials vary with the character of the ore? What is the function of the slag formed from the flux? What is the chemical nature of the slag?

980. Make a labeled diagram of a blast furnace. What are its dimensions? Of what materials does it consist?

981. Of what does the charge introduced into the furnace consist? Describe fully the chemical changes, directly and indirectly, that take place in the reduction of the ore. Of what do the gases that issue from the top of the furnace consist? What use is made of them?

982. What kind of iron is made in the blast furnace? What impurities does it contain? What is its general percentage composition?

983. What are the properties of pig iron, or cast iron? What are its important uses?

984. Describe the construction of the reverberatory, or puddling furnace. What kind of iron is made in it?

985. With what is the hearth of the puddling furnace lined? Of what does the charge that is added consist?

During the process what is the first effect of the flame upon the cast iron? What becomes of the carbon and sulfur? of the silicon and phosphorus? What is the source of the oxygen? What effect does the removal of the impurities have on the melting point of the iron? What form does the iron begin to assume? To what treatment do the workmen subject it? What disposition is finally made of the iron?

986. What is the composition of wrought iron? What are its distinguishing characteristics? State its uses.

987. What is the starting point in the manufacture of steel? Name three processes.

988. Describe the construction of a Bessemer converter. What is its approximate capacity?

989. Describe the conversion of molten cast iron into steel by the Bessemer process. What chemical changes occur? What must be added at the end? How long does the process take? What are the chief advantages of this process? What are its weak points? What keeps the iron molten?

990. With what two sorts of materials is the Bessemer converter lined? When is the acid lining employed? the basic lining?

991. Make a diagram of the open hearth furnace. For what kind of pig iron is it especially adapted? What sort of fuel is used? What is the function of the brick checkerwork on either side?

992. With what is the hearth of the furnace lined? Of what does the charge consist? Describe the process of converting the iron into steel. In what forms are the impurities removed from the iron? What is the source of the oxygen? What tests are made toward the end of the process? What substances are added just before pouring and for what purposes?

993. How long does the open hearth process take? In what respects is open hearth steel superior to Bessemer steel? What use is made of the slag from the puddling and open hearth furnaces?

994. Describe the process of making steel by *a*) the crucible process, *b*) the cementation process. For what are these kinds of steel used?

995. What effect upon the properties of steel is caused by *a*) sulfur? *b*) phosphorus?

996. What is the general composition of steel? State its distinguishing characteristics.

997. Name six large and important uses of steel.

998. What is the composition of tool steel?

999. What is meant by tempering steel? Describe and explain the process by which this is done.

1000. Name five elements with which steel is alloyed in the production of special steels. What property does each of these elements give to steel? What is "platinite"? "invar"?

1001. Mention five substances including three metals that are used as protective coatings for iron and steel. Explain the chemistry involved in the rusting of iron.

COMPOUNDS OF IRON

1002. What two series of compounds does iron form? In what respect do they differ?

1003. Give the names and formulae of the iron oxides. What is Venetian red? rouge? lodestone?

1004. What is the chemical name and formula of copperas? What is another common name for this substance? Of what industry is it a by-product? Point out its use in *a*) the preparation of ink, *b*) the purification of water, *c*) as a mordant, *d*) as an agricultural spray.

1005. Give the chemical name and formula of iron pyrites. What are its uses?

1006. In general what are the colors of *a*) ferric salts? *b*) ferrous salts? Which form is the more stable? Why?

1007. Why do many iron salts in solutions give an acid reaction? Illustrate.

1008. How may ferrous and ferric hydroxides be precipitated? Write the equations for the reactions.

1009. Write formulae for the ferrous and ferric forms of each of the following:—*a*) chlorides, *b*) sulfates, *c*) nitrates.

1010. State the color obtained in each case by adding to solutions of ferrous and ferric salts respectively a few cubic centimeters of a solution of *a*) potassium ferrocyanide, *b*) potassium ferricyanide, *c*) potassium sulfocyanate.

1011. Give one characteristic test for *a*) a ferrous salt, *b*) a ferric salt. How would you test for each in the presence of the other?

1012. If to a solution of ferric chloride in a test tube we add potassium ferricyanide solution and expose to the sunlight what is the result? If now we add to the mixture a solution of oxalic acid and continue to expose to the sunlight what is the result? Explain.

1013. What salts are used in the preparation of blue print paper? Describe the process. What change takes place upon exposure of this paper to sunlight? How is the exposed paper developed and fixed?

1014. Describe the oxidation of *a*) ferrous sulfate to ferric sulfate, *b*) ferrous chloride to ferric chloride. Write equations for the reactions. Where has oxidation entered into these reactions? What has happened to the iron?

1015. Describe the reduction of ferric chloride to ferrous chloride. Write equations for the reactions that occur in the production of the nascent hydrogen and the reduction of the iron.

1016. Give new definitions for oxidation and reduction.

1017. What is iron rust? How may spots of iron rust be removed from white goods?

1018. Tell how each of the following may be removed:—

a) ink spots, *b*) coffee and tea stains, *c*) sugar stains, *d*) grease spots, *e*) gum, *f*) fruit stains, *g*) varnish, *h*) iodine.

1019. What is *a)* Prussian blue? *b)* Turnbull's blue? For what are they used?

NICKEL AND COBALT

1020. What are the constituents of *Monel metal,* its properties and uses? Name two other alloys of nickel with the constituents of each.
1021. What effect does nickel have upon steel?
1022. Why is nickel often used as a coating for iron? How is the metal applied? What other metal must first be deposited upon the iron?
1023. What is the use of cobalt in the glass industry?
1024. Describe the cobalt nitrate test for *a*) aluminum, *b*) zinc, *c*) magnesium.
1025. Describe three methods that might be employed for determining the metallic portion of a salt in solid form.
1026. How would you identify each part of the following compounds:—sodium sulfate? zinc chloride? magnesium chloride? ferrous chloride? silver nitrate? barium carbonate? cobalt nitrate?

COPPER

1027. Why was copper one of the earliest metals to be used?
1028. Name three of the copper ores and three of the copper regions of the United States.
1029. Describe the extraction of copper from an ore that contains no sulfur.
1030. Describe the processes for the extraction of copper from one of its sulfide ores.
1031. Describe the electrolytic refining of copper and state

the chemical changes that occur. Of what does the anode consist? the cathode? the electrolyte? What "impurities" are recovered?

1032. Name the physical properties of copper and the uses depending upon them.

1033. State the action upon copper of *a*) hydrochloric acid, *b*) sulfuric acid, dilute and concentrated, *c*) nitric acid, *d*) moist air.

1034. What evidence is there *a*) that a chemical change occurs when copper is heated in the air? *b*) that during the heating the copper takes something from the air? How could you determine what that something is?

1035. Name five alloys of copper and the constituents of each.

1036. By reference to the replacement series of the metals explain why zinc and copper placed in a solution of sulfuric acid will develop a difference of electrical potential.

1037. In the electrolytic refining of copper why do the gold and silver drop to the bottom of the bath and not go into solution?

1038. What are the two series of copper compounds? What are the colors of the cupric salts? Why do they all have a blue color in solution?

1039. By what test could you determine the presence of copper in a silver coin?

1040. What are the formula and common name of crystallized copper sulfate?

1041. Name uses of copper sulfate. Of what processes is it a by-product? Why is its solution slightly acid to litmus?

1042. What is "Bordeaux mixture"? For what is it used?

1043. Compare the uses of alum and copper sulfate in the purification of water.

1044. Why will a little copper sulfate solution placed in a hydrogen generator start the action?

1045. From 1,000 grams of crystallized copper sulfate how many grams of water can be driven off?

MERCURY

1046. Name the principal ore of mercury. Describe the metallurgy of mercury. How is the metal purified?
1047. State the physical properties of mercury. Define amalgam. Name two processes in which amalgams are important.
1048. Discuss the action of the common acids upon mercury.
1049. Why is mercury especially adapted to use in thermometers and barometers? Name other uses of mercury.
1050. For what is mercuric oxide historically important?
1051. What is calomel? For what is it used?
1052. Give the chemical name and formula of corrosive sublimate. By what other name is it also known? For what is it used? Why is its use dangerous?
1053. Compare calomel and corrosive sublimate as to solubility. How may the two be distinguished?

SILVER

1054. How does silver occur in nature?
1055. What is the principal source of silver? Describe Parke's process for the separation of silver from lead. What other valuable metal also separates with the silver? How is the zinc separated from its alloy with silver and gold? How are the silver and gold freed from the small quantity of lead still mixed with them?
1056. Describe the "parting" of the silver and gold by means of sulfuric acid. How is the silver itself obtained from the resulting solution? What is a valuable by-product of this process? How is the

gold separated from any platinum that it may contain?

1057. Name five physical properties of silver.

1058. What is *a*) coin silver? *b*) sterling silver? Why is plated ware softer than sterling silver?

1059. Discuss the action upon silver of *a*) moist air, *b*) sulfur compounds, *c*) hydrochloric, sulfuric, and nitric acids.

1060. Name two articles of food that will tarnish silver. To what is the tarnishing due? Why do the combustion products of burning gas and coal tarnish silver?

1061. Describe the electrolytic process for *a*) refining silver, *b*) silver plating.

1062. Give the chemical name and formula of "lunar caustic." How is it prepared? What are its uses? Describe the silver nitrate test for chlorides.

1063. What is the test for silver? How would you prepare pure silver nitrate from a silver coin?

1064. What salts does silver form with the halogens? What is the effect of sunlight upon these salts? The presence of what sort of matter aids this change?

1065. Describe the preparation of a photographic plate. State the effect of exposing this plate in a camera to the light from some object focused upon it. Why is the image as yet only latent upon the plate?

1066. What sort of a chemical agent is a developer? Name two compounds used as developers. Describe the process of developing and the changes which it produces in the plate.

1067. In what does the "fixing" consist? Why is this step necessary? Of what does the fixing bath consist? Describe the process? Why is the image on the plate now called a negative?

1068. How is the printing paper prepared? Describe the process of printing a picture from the negative. Why is this picture called a positive?

1069. Describe the toning of the print. What chemical principle already studied is made use of in this process?

1070. How could you distinguish between mercuric nitrate and silver nitrate? Why is silver nitrate kept in amber-colored bottles?

1071. Silver ware may be cleaned by putting it in an aluminum kettle with a solution of baking soda and heating. Explain the action.

TIN

1072. What is the chief ore of tin? Where is it found? Describe its metallurgy.

1073. What is block tin? What are its uses? Why is block tin used in stills for the purest water?

1074. State the physical properties of tin. What is the action of tin with respect to *a*) moist air? *b*) acids?

1075. What is tin plate? How is it prepared? What are its uses? Compare tin and zinc as protective coatings for iron.

1076. Name four alloys of tin and the constituents of each. What are the properties and uses of these alloys?

1077. What are the two series of tin salts? What is the valence of tin in each? What use is made of stannic and stannous hydroxides in dyeing?

LEAD

1078. State the common name, chemical name, and formula of the most abundant lead ore.

1079. Describe the most important method for the extraction of lead from its ore as to *a*) the furnace, *b*) the charge, *c*) the chemical changes, *d*) subsequent treatment to remove impurities and soften the lead, *e*) desilverization.

1080. What are the physical properties of lead?

1081. What is the action upon lead of *a*) air? *b*) the common acids? *c*) water?

1082. Name four important uses of lead and the properties upon which these uses depend. What are the advantages and disadvantages of using lead for water pipes?

1083. Name four alloys of lead and the constituents of each.

1084. Give the names, formulae, and uses of two oxides of lead.

1085. Describe the construction of the lead storage cell. State the chemical changes that take place in *a*) charging, *b*) discharging. Why may a hydrometer be used to determine the state of charge? What is "stored up"?

1086. Describe a test for lead salts in solution. How can you distinguish between lead, silver, and mercurous chlorides?

1087. State the formula and solubility in water of each of the following:—sugar of lead, lead nitrate, lead chloride, lead chromate, lead sulfate, lead sulfide.

1088. Describe fully the old Dutch process of making white lead. What is the approximate formula of white lead?

1089. Discuss the use of white lead as to *a*) its advantages, *b*) objections to its use, *c*) substitutes in part or whole for white lead.

1090. Discuss paints as to *a*) the vehicle, *b*) the body, *c*) the pigment. Give examples of each.

1091. What is the chemical action in the "drying" of paints? Of what do "dryers" consist and what is their action? What is the function of red lead in paints?

1092. What is chrome yellow? How is it prepared?

1093. Why do houses and oil paintings frequently blacken with age?

1094. How many grams of lead sulfide wll be precipitated by passing hydrogen sulfide into a dilute solution of

3.31 grams of lead nitrate until precipitation is complete? What weight and what volume of hydrogen sulfide will be required?

MANGANESE AND CHROMIUM

1095. Name at least four uses of manganese dioxide and point out the particular application in each case.
1096. With reference to potassium permanganate state *a*) its formula, *b*) properties, *c*) uses.
1097. State the visible effect and the chemical action resulting from passing sulfur dioxide into a dilute solution of potassium permanganate. What new substance has been formed? How could it be tested for?
1098. How may potassium permanganate solution be used as a test for organic matter in water?
1099. How could you show the presence of carbon in an impure sample of manganese dioxide?
1100. What is the chief chemical property of chromates and dichromates? Name two laboratory uses of potassium dichromate. What is its use in the tanning of leather?
1101. State uses of the metals chromium, molybdenum, tungsten, and vanadium. What properties of tungsten fit it for use as an electric light filament?

PLATINUM AND GOLD

1102. What is the chief source of the world's supply of platinum? How have war and Bolshevism interfered with the supply and price of this precious metal? In what form does native platinum occur?
1103. State the physical properties of platinum.
1104. In what form is platinum used as a catalytic agent? Name several important applications of the catalytic action of platinum. To what physical property of the metal does this action seem to be due?

1105. State the chemical properties of platinum and the precautions that must be observed in its laboratory use. Upon what properties does this use depend?
1106. Name other uses of platinum. What substitutes have been found for some of these uses?
1107. How does native gold occur?
1108. Describe two methods of mining gold.
1109. Describe each of the following processes for the extraction of gold:—*a*) amalgamation process, *b*) cyanide process. Point out the great economic importance of the latter process.
1110. In the metallurgy of what other ores is gold obtained as a by-product? Describe the method of its separation.
1111 State the physical and chemical properties of gold. What is meant by the term "18 carats fine"? "solid gold"?
1112. How can you distinguish between gold and brass? How does a jeweler determine the fineness of gold?
1113. Mention the uses of gold.

THE RADIOACTIVE ELEMENTS

1114. What are the radioactive elements? Explain what is meant by radioactivity? How could you determine whether a substance is radioactive? Name localities where radioactive minerals are found.
1115. What was the first radioactive element to be discovered? When and by whom was this discovery made?
1116. When, by whom, and from what mineral was the discovery of radium made? Tell the story of its discovery.
1117. What are the products of the disintegration of radium? What three kinds of rays are given off in this disintegration and what are the characteristics of each?
1118. What energy change accompanies the disintegration

of radium? Show why this does not violate the law of conservation of energy. What is the life cycle of radium?

1119. What seems to be the source of radium? What fact indicates that the "birth" and "death" of radium proceed at equal rates and that, therefore, the quantity of radium in the earth can never increase?

1120. How does *radio lead,* the end product of the disintegration of radium, differ from lead obtained from other sources?

1121. Discuss the uses of radium in the treatment of disease. In what form is the energy of radium applied in this treatment?

1122. What important changes in our theory of atoms have been brought about by the knowledge of radioactivity?

1123. Since radium actually changes into other elements why do we still regard it as an element?

1124. State the purpose of thorium in the Welsbach gas mantle.

SOME COMPOUNDS OF CARBON

1125. What was the original significance of the term "organic," as applied to chemistry? Why has this significance since disappeared? What is the present meaning of the term "organic chemistry"?

1126. Name six of the most important classes of carbon compounds.

1127. Define hydrocarbon. Name two of the most important series of hydrocarbons. By what group of atoms do the successive members of each of these series differ? What is such a series called?

1128. What are the two chief sources of hydrocarbons?

1129. What is the chemical nature of crude petroleum? Describe the process of refining and purifying it. Why is it possible to separate the various constituents by this method? In the purification of the

products of this process what is the purpose of *a*) the sodium hydroxide? *b*) the sulfuric acid?

1130. What are the important products of the above process and the uses of each?

1131. What products are obtained from the residue left in the distilling retort and how are they worked up? How do these products vary with the character of the crude oil?

1132. What is meant by the "cracking of oils" and what is its purpose?

1133. Discuss the distillation of oil shales as a future source of gasoline. Where in this country are such shales found?

1134. How does the physical state of the members of the methane series of hydrocarbons vary with increase in the number of carbon atoms? Write the graphic formulae of the first three members of the series. Why is this series called an homologous series?

1135. Write the formulae for the chlorine substitution products of methane.

1136. What is the name of the last one of these substitution products? What are its properties and uses? Under what trade names is it placed upon the market?

1137. Describe the laboratory method for the preparation of chloroform. State another method for its preparation.

1138. Write the formula of chloroform. Show the relation of chloroform to methane. What are its properties and uses?

1139. What is the formula of iodoform? How is it prepared? What are its properties? What important use does it have in surgery? Describe the iodoform test for alcohol.

1140. State the formulae and names of the alcohols corresponding to the first three members of the methane series. How may they be regarded as derivatives of the methane series? What group is common to

all three of them? How is the name of the alcohol derived in each case? What would the formulæ of these compounds indicate as to their chemical character?

1141. What is the common name of methyl alcohol? Describe its preparation. What are the other products of this same process?

1142. State the properties and the uses of wood alcohol. What precautions must be observed in handling it? What are the ill effects of introducing it into the human system?

1143. Describe a method for determining the presence of wood alcohol in beverages and extracts.

1144. What product results from the oxidation of wood alcohol by means of hot copper oxide? Write the equation.

1145. What are the formula, properties, and uses of formaldehyde? What is formalin?

1146. Describe a method for determining the presence of formaldehyde in milk.

1147. Give the chemical name and formula of the second oxidation product of wood alcohol. Show how carbon monoxide may be made from this acid.

1148. Give the chemical name and formula of grain alcohol. Of what hydrocarbon is it a derivative?

1149. Describe the laboratory preparation of ethyl alcohol by the fermentation of glucose. Write the equation for the reaction. What is the function of the yeast? What visible evidence is there of chemical action?

1150. Describe the process of separating and purifying the alcohol from the above mixture. How may the alcohol thus obtained be converted into absolute alcohol? Define absolute alcohol.

1151. Define *a*) enzyme, *b*) fermentation. To what class of chemical action does fermentation belong?

1152. State the properties of ethyl alcohol. Name important laboratory, medical, and commercial uses of alcohol.

1153. Describe the commercial preparation of alcohol from the starch of cereals. Write the equations for the reactions involved. What is malt and what is its function?

1154. What is denatured alcohol? Why is alcohol thus treated?

1155. Ethyl alcohol and methyl ether both have the same formula, C_2H_6O. Using these compounds as examples, explain what is meant by *a*) empirical formulae, *b*) structural formulae, *c*) isomers.

1156. Describe the process for the commercial preparation of vinegar from cider or grape juice. What two kinds of fermentation occur? To what is each fermentation due? Write the equations for the chemical reactions in each case.

1157. By what process is the concentrated acetic acid of commerce manufactured? What are its uses?

1158. Give the sources and uses of each of the following:— tartaric acid, cream of tartar, lactic acid, citric acid, oxalic acid.

1159. What is an ethereal salt, or ester? Where in nature do esters occur? In what artificial preparations are they of importance? How may they be prepared?

1160. Describe the laboratory preparation of ethyl acetate. How may it be recognized? Write the equation for its formation. To what reaction in inorganic chemistry does this correspond?

1161. To what class of compounds do the fats belong? What is the chemical effect of heating a fat with an alkali? Illustrate. What name is given to the process? Of what industry is this reaction the basis?

1162. Describe the laboratory preparation of soap. Write the equation for the reaction.

1163. Describe the commercial manufacture of soap as to *a*) oils and fats used as soap stock, *b*) shape and capacity of the kettles, *c*) the raw materials run into the kettles, *d*) the treatment during the saponifica-

tion, *e*) the "salting out," *f*) the separation and subsequent treatment of the soap, *g*) the separation of the glycerine from the sub-lye after the soap has been removed.

1164. How are the following soaps prepared:—transparent soap, floating soap, naptha soaps, scouring soaps, soap powders.

1165. For what are rosin and water-glass used in soaps?

1166. Define soap. Name two soluble soaps and two insoluble soaps.

1167. Discuss fully the cleansing action of soap. Why does soap give an alkaline reaction?

1168. What substance is a very valuable by-product of soap manufacture? To what class of organic compounds does it belong?

1169. Describe the preparation of nitroglycerin. Write the equation for the reaction. To what class of compounds does it belong? What is dynamite?

1170. How is nitroglycerin detonated? To what is its tremendous explosive violence due? What is cordite?

1171. Of what does butter consist? How does it differ from oleomargarine? From what and by what process is oleomargarine made?

1172. What is meant by the hydrogenation of oils? Of what commercial importance is this process? How is it carried out?

1173. Describe the preparation of ethyl ether from ethyl alcohol. What is the function of the sulfuric acid used? Write the equation for the reaction. Give the formula, properties, and uses of ether.

1174. Define carbohydrate and point out the significance of the term. Name with formulae three carbohydrates.

1175. Give the chemical name and formula of cane sugar. What are its sources?

1176. Describe the extraction and refining of sugar, touching upon the following points:—*a*) the expression

of the juice, *b*) its concentration and clarification, *c)* boneblack filters, *d)* vacuum pans, *e)* the centrifuge.

1177. What is *a*) glucose? *b*) fructose? What is their formula? What fact of carbon compounds do they illustrate? What are their sources?

1178. Describe the Fehling test for glucose.

1179. What is meant by the *inversion* of cane sugar? How can it be accomplished? Write the equation for the reaction. Of what commercial use is this process? How can the product be tested for?

1180. What is the formula of starch? How may starch be changed into glucose? Write the equation for the reaction. How is this process commercially applied?

1181. Describe the commercial preparation of starch from corn as to *a*) grinding and separation of the germ, *b*) separation of the bran, *c*) separation of the gluten and starch.

1182. Describe a test for starch.

1183. What are the formula and sources of cellulose?

1184. Describe the preparation and state the uses of *a*) nitrocellulose, or guncotton, *b*) collodion, *c*) celluloid.

1185. Describe the preparation of *a*) mercerized cotton, *b*) artificial silk.

1186. Describe laboratory methods for distinguishing cotton, wool, silk, and linen. How would you test for cotton in "woolen goods"?

1187. Describe the manufacture of paper as to *a*) preliminary treatment of the raw material, *b*) chemical treatment and bleaching of the pulp, *c*) substances added, with reasons for their addition, *d)* mechanical process.

1188. Name three classes of carbon compounds, the members of which are essential constituents of human foods. Give examples of each. What are the value and functions of each?

1189. Describe tests for each of the three principal kinds of foods.

1190. State *a*) four processes for preserving foods, *b*) six chemical compounds used as food preservatives, *c*) three coal tar compounds used in foods.

1191. Distinguish between a disinfectant and an antiseptic. Give examples of each.

1192. What is the source of coal tar? Previously to the war what disposition was made of this by-product in this country? In what sort of ovens was coal formerly coked? Describe a modern by-product coke plant.

1193. Name five of the most important compounds obtained in the refining of coal tar. By what process is coal tar refined?

1194. Name important derivatives of the above compounds.

1195. Tell the story of the discovery of the first coal tar dye. Describe the subsequent development of the dye industry in Europe.

1196. Discuss the phenomenal growth of the coal tar industry in this country under the exigencies of war. Why is this industry a fundamental resource both of peace and war?

1197. What is toluol? Describe the preparation of trinitrotoluol. State its characteristics as an explosive.

1198. What are the chemical name and formula of carbolic acid? Show how picric acid is derived from it. What are the uses of picric acid? Compare it with TNT as an explosive.

1199. What is *Bakelite* and how is it prepared?

1200. Show the importance of coal tar compounds in *a*) medicine, *b*) surgery, *c*) photography, *d*) war.

1201. Classify as *a*) esters, *b*) hydrocarbons, *c*) alcohols, *d*) carbohydrates, the following products:—glycerin, starch, beef fat, kerosene, sugar, nitroglycerin, olive oil, carbolic acid, acetylene, and paraffin.

COLLEGE BOARD QUESTIONS*

ORDINARY EXAMINATION QUESTIONS
1916–1920

NOTE:—In some instances the questions within the groups of the following classification overlap each other owing to the mixed character of the questions themselves.

GROUP I

CHEMICAL EQUATIONS

1. Write equations for the following reactions, using formulas throughout. To receive credit, the equations must be absolutely correct.
   a) Sodium acid carbonate + sulfuric acid =
   b) Carbon dioxide + heated carbon =
   c) Silver sulfate + barium chloride =
   d) Copper + hot concentrated sulfuric acid =
   e) Hydrogen sulfide burned in excess of air =
   f) Potassium chlorate heated with manganese dioxide =
2. Write equations for the following reactions, using formulas throughout. The equations must be correct in every particular.
   a) Ammonium nitrate (heated) =
   b) Ferric chloride + zinc =
   c) Methane (marsh gas) + oxygen (ignited) =
   d) Hydrogen sulfide + silver nitrate =
   e) Copper oxide (heated) + hydrogen =
   f) Calcium oxide + sodium carbonate + water =
3. Write equations for the following reactions, using formulas throughout. To receive credit, the equations must be correct in every particular.

* By permission of the College Entrance Examination Board.

a) Chlorine (gas) + hydrogen (gas) =
b) Sodium carbonate + carbon dioxide + water =
c) Ammonium carbonate + copper (cupric) chloride =
d) Ferric oxide + carbon (heated) =
e) Ammonia completely burned in oxygen =
f) Silver sulfate + zinc =

4. Illustrate by equations the action of dilute sulphuric acid on *a*) zinc, *b*) calcium oxide, *c*) ammonium hydroxide, *d*) sodium carbonate, *e*) ferrous sulphide, *f*) barium chloride. Name the type of reaction which occurs in each case. Formulas must be used throughout and the equations properly balanced to receive credit.
5. Write equations for the following reactions, using formulas throughout. To receive credit, the equations must be absolutely correct.
   a) Silver nitrate + ferric chloride =
   b) Sodium carbonate + nitric acid =
   c) Ammonium chloride + calcium hydroxide =
   d) Zinc hydroxide + hydrochloric acid =
   e) Combustion of phosphorus in air =
   f) Silver chloride + zinc =

Group II

LABORATORY METHODS

6. *a*) Describe in detail how you should determine experimentally either 1) the hydrogen equivalent of some metal, or 2) the weight of a liter of some gas.
   b) What is meant by the relative activity of the metallic elements? Arrange in order of decreasing activity the following:—gold, hydrogen, zinc, sodium, copper. (The arrangement must be correct throughout to receive credit.)
7. Answer five parts of this question. How could you demonstrate experimentally that:—*a*) Nitric acid is an oxidizing agent? *b*) Sulphur dioxide is a reducing

agent? *c*) Copper sulfate is a salt? *d*) Alcohol contains carbon? *e*) Kerosene is a mixture? *f*) Litharge contains lead?

8. Answer five of the following:—*a*) How would you make ferrous chloride from ferric chloride? *b*) Ferric chloride from ferrous chloride? *c*) White lead from lead? *d*) Sodium sulfite from sodium hydroxide? *e*) Sodium hypochlorite from sodium hydroxide? *f*) Alum crystals from aluminum sulfate?
9. Describe a method for the laboratory preparation of the following substances:—*a*) sodium chloride, *b*) calcium carbonate, *c*) nitric oxide. What property has sodium chloride which makes it possible to separate it? calcium carbonate? nitric oxide?
10. How could you make:—*a*) Zinc sulfate from zinc chloride? *b*) Copper from copper sulfate? *c*) Ferric oxide from ferric chloride? *d*) Sodium sulfite solution from sulfur?
11. How should you proceed to produce the first-mentioned substance from the second in four of the following cases? Describe each step in the process.
    a) Nitrogen from the atmosphere;
    b) Kerosene from crude petroleum;
    c) Sulfuric acid from sulfur;
    d) Lime water from marble;
    e) Hydrochloric acid from sulfuric acid.
12. How could it be determined by chemical means if a sample of *a*) water were hard or soft? *b*) hard water had temporary or permanent hardness? *c*) washing powder contained sodium carbonate? *d*) metal was gold or brass? *e*) beverage contained alcohol?
13. *a*) Outline briefly a laboratory method for obtaining a pure sample of 1) sulfur crystals from powdered sulfur, 2) ferric hydroxide from iron.
    b) Name two substances which in reacting upon each other can yield 1) an element by reduction of a compound of that element, 2) an element by oxidation of a compound of that element, 3) a soluble salt by

direct combination, 4) an insoluble sulfide by precipitation.

14. Describe a method for the preparation of three of the following substances:—*a*) sodium, *b*) nitric acid, *c*) hydrogen sulfide, *d*) calcium carbonate. How would you separate the desired product, in each case, from the reaction mixture?

15. How could you show experimentally that:—
    a) fused calcium chloride is a deliquescent substance?
    b) carbonic acid is unstable?
    c) nitric acid is an oxidizing agent?
    d) diamond is a form of carbon?
    e) sugar is not an electrolyte?
    f) a hydrocarbon contains hydrogen?

16. Mention very briefly *any* means of identifying with certainty each of the following gases:—hydrogen, nitrogen, carbon dioxide, sulfur dioxide, nitrous oxide, chlorine, carbon monoxide, hydrogen sulfide, oxygen, ozone.

17. Describe an experiment illustrating the quantitative character of chemical action, including apparatus, method, and precautions. Show how the data found in the experiment warrant the conclusion reached. The data may be represented by letters.

18. *a*) Outline a method by which pure silver nitrate could be obtained from a silver coin. What other metal is present in the coin, and how may it be identified?
    b) Give a method for the preparation of chlorine from common salt.

19. Describe a method for the laboratory preparation of three of the following substances:—*a*) sodium nitrate, *b*) ethyl alcohol, *c*) barium sulfate, *d*) hydrochloric acid. What property has the desired product in each case which makes it possible to separate it?

20. How would you prove, by chemical means, the presence *a*) of carbon monoxide if mixed with sulfur dioxide? *b*) of hydrogen if mixed with dry air (if the

amount of hydrogen is too small to make the mixture explosive)? *c*) of gold in copper? *d*) of sulfuric acid in a solution of hydrochloric acid?

21. *a*) Show by formulas how an anhydride is related to the corresponding acid or base.
b) Suggest, by writing appropriate equations, four different methods for making calcium sulfate from calcium, oxygen, sulfur trioxide, and water.

Group III

COMMERCIAL APPLICATIONS

22. Answer four of the following questions:—
a) Explain the cleansing action of soaps. Of what substances are washing powders likely to be composed?
b) Describe one method of converting pig iron into steel.
c) Explain upon a chemical basis the use of ozone in the purification of water.
d) Name two products of commercial importance that can be obtained, by chemical change, from starch.
e) What rôle does each of the three general classes of foods play in nutrition?

23. Select three of the substances:—chlorine, potassium nitrate, zinc, slaked lime, and give the following information in regard to each:—*a*) Name a naturally occurring material from which the substance is commonly made. *b*) Write the equation or equations representing the preparation of the substance from this material. *c*) Give one important commercial use.

24. *a*) Describe the electrolytic process for silver plating. *b*) Of what chemical elements are ordinary fuels composed? What products are formed by their combustion? Aside from expense, what are the disadvantages of sulfur as a fuel?

25. Considering each of the following substances sep-

arately, name two important products made from it directly or by admixture or reaction with other substances:—*a*) lime, *b*) salt, *c*) crude petroleum, *d*) coke, *e*) sand.

26. *a*) Explain the use of cream of tartar in baking powders.
b) When a compressed mixture of air with gasoline is exploded in a confined space, what substances may be formed? What difference in the nature and relative amounts of the products may be expected 1) if the amount of gasoline is small in comparison with the air present? 2) if the proportion of gasoline is unduly large?

27. *a*) What substance burns with a blue flame on the top of a coal fire? Write two equations for the reactions involved in the formation of this substance; write an equation for the reaction involved in its combustion.
b) Define the term "by-product." Show how a valuable by-product is obtained in some chemical process of commercial importance.

28. *a*) Mention one important industrial process depending on each of the following phenomena respectively:—reduction, catalysis, crystallization, electrolysis.
b) State what impurities render water unfit for 1) drinking purposes, 2) steam boilers, 3) laundries; and outline a different practical method adapted to improving the water in each case.

Group IV

PROBLEMS

29. *a*) If 50.0 grams of calcium carbonate, $CaCO_3$, are added to 50.0 grams of hydrochloric acid, HCl, in water solution; which substance remains in excess? What is the weight of this excess? (Atomic weights:—Ca 40, Cl 35.5, O 16, C 12, H 1.)
b) What volume of nitric oxide, NO, measured under

standard conditions, can be obtained by adding 10.0 grams of copper to excess of dilute nitric acid according to the equation:—

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 4H_2O + 2NO?$$

(Atomic weights:—Cu 64, O 16, N 14, H 1. One liter of nitric oxide at 0° C. and 760 m.m. weighs 1.34 grams.)

30. *a*) Ten liters of a gas whose formula is C_2H_6O are completely burned in oxygen. How many liters of oxygen gas are required for its complete combustion? How many liters of carbon dioxide should result? All volumes are measured under the same conditions of temperature and pressure.

b) If the temperature of a gas enclosed at an initial pressure of one atmosphere is decreased from 37° C. to 27° C. without change in volume, what will be the final value of the pressure?

31. *a*) State Gay-Lussac's law of combining volumes. What volume of oxygen is required for the complete combustion of five liters of acetylene, C_2H_2? All measurements are to be made under the same conditions of temperature and pressure.

b) One liter of gas A weighs 1.98 grams. One liter of gas B weighs 0.77 gram, under the same conditions. The molecular weight of A is 44. What is the molecular weight of B?

32. *a*) How many grams of sodium hydroxide will be required to neutralize 9.8 grams of sulfuric acid? Name the products formed and determine the weight of each product. (Atomic weights:—H 1, O 16, Na 23, S 32.)

b) What volume will one liter of gas at 136.5° absolute have at 136.5° C., pressure remaining the same?

33. *a*) How many grams of water of crystallization are there in the crystallized barium chloride ($BaCl_2 \cdot 2H_2O$) obtained from 10 grams of barium? (Atomic weights:—Ba 137, Cl 35.5, O 16, H 1.)

b) How many cubic centimeters of ammonia gas,

NH_3, under standard conditions, can be obtained from 5.00 grams of ammonium phosphate $(NH_4)_3PO_4$, by treating it with sodium hydroxide in excess? $(NH_4)_3PO_4 + 3NaOH = Na_3PO_4 + 3H_2O + 3NH_3$. (Atomic weights:—P 31, Na 23, O 16, N 14, H 1.) One liter of ammonia weighs 0.77 gram.

34. *a*) What weight of sulfur dioxide will occupy a volume equal to that of 42 grams of nitrogen at the same temperature and pressure? (Atomic weights:—S 32, O 16, N 14.)

b) What volume of a solution of hydrochloric acid containing 73 grams per liter would suffice for the exact neutralization of the sodium hydroxide obtained by allowing 0.46 gram of metallic sodium to act upon water? (Atomic weights:—Cl 35.5, Na 23, O 16, H 1.)

35. *a*) What is the percentage of ammonia in cuprammonium sulfate, $CuSO_4 \cdot 4NH_3 \cdot H_2O$? (Atomic weights:—Cu 64, S 32, O 16, N 14, H 1.)

b) What weight of pure sodium bicarbonate, $NaHCO_3$, must be treated with excess of acid to produce 250 liters of carbon dioxide measured at 0° C. and 1520 m.m. pressure? (Atomic weights:—Na 23, O 16, C 12, H 1. One liter of carbon dioxide at 0° C. and 760 m.m. weighs 1.98 grams.)

36. A dirigible balloon at sea-level contains 400,000 cubic feet of gas measured at a pressure of 774 m.m. of mercury and at a temperature of 27° C. It rises to an elevation at which the pressure is reduced to 430 m.m. and the temperature to –23° C. What is the volume of the gas under the latter conditions, assuming that none is allowed to escape from the containers?

37. If 540 grams of silver react with an excess of concentrated sulfuric acid according to the equation $2\,Ag + 2\,H_2SO_4 = Ag_2SO_4 + 2\,H_2O + SO_2$, what weight of silver sulfate, and what volume of sulfur dioxide measured under standard conditions of temperature and pressure, will be formed? (Ag 108, S 32, O 16, H 1.)

NOTE:—One liter of sulfur dioxide at 0° C. and 760 m.m. weighs 2.9 grams.

GROUP V

CHEMICAL LAWS AND THEORY

38. *a*) What forms of energy are manifest when a mixture of hydrogen and oxygen is exploded? From what source are these forms of energy derived? Apply the law of conservation of energy to this reaction.

b) Excess of phosphorus is allowed to act on air at atmospheric pressure in a sealed flask. When the reaction is complete, 1) What is the pressure (approximately) in the flask, the temperature remaining the same? 2) How does the weight of the flask and contents after the reaction compare with the weight before? State the law upon which the latter conclusion is based.

39. *a*) What is meant by the term "reversible reaction"?

b) Under what three conditions will a reaction proceed to completion?

c) Illustrate each of these conditions separately by writing the equation of a suitable reaction, showing which condition is fulfilled in each case.

40. Considering each of the following statements separately, explain why you consider it to be an experimental fact or an assumption:—*a*) The composition of a given compound does not vary. *b*) Two atoms of iron have the same weight. *c*) The materials composing foods cannot be put out of existence. *d*) Some compounds ionize when dissolved in water. *e*) Five grams of hydrogen may be found united with forty grams of oxygen or with eighty grams. Name the theory or law which applies in each case.

41. *a*) What classes of substances are electrolytically dissociated? What is the effect of dilution on the degree of dissociation of the substance? How may the degree of dissociation be diminished without changing materially the volume of the solution?

b) Show how the electric current is conveyed through a solution of $CuSO_4$, and indicate the reactions that take place at the poles.

42. *a*) Which contains the more energy under the same conditions of temperature and pressure, a mixture of 1 gram of hydrogen and 8 grams of oxygen or 9 grams of water? Give the reason for your conclusion.
b) Name two elements having more than one valence. Illustrate each of the valences of these elements by constructing a formula containing also one element of constant valence. Write above the symbol of each element, in each formula, its valence.

43. *a*) Given the valence of A as three, derive the probable valences of B, C, and D from the following formulas:—A_2B_3, B_2C, B_5D_2. What would be the formula of a compound of A with C?
b) Prove that the law of definite proportions is a necessary consequence of the atomic theory.

44. *a*) What is a reversible reaction? Illustrate by means of an equation.
b) Under what three conditions will a reaction go to completion?
c) On the basis of the electrolytic dissociation theory, how would you explain 1) the neutralization of an acid by a base? 2) the changes that take place when a solution of copper sulfate is electrolyzed between copper electrodes?

45. Arrange three metals in the order of decreasing activity. Describe in detail three experimental methods by which the correctness of the suggested order may be proved.

46. *a*) Write an equation illustrating a reaction between two salts in solution, which does not go to completion. Explain why this reaction does not go to completion.
b) How does a water solution of copper sulfate react with litmus? Explain.

47. *a*) Apply Avogadro's law in finding the volume of carbon dioxide formed from the burning of 4 liters of

carbon monoxide in oxygen, provided all of the gases are measured at the same temperature and pressure.

b) Name the components in a water solution of ammonia.

Group VI

MISCELLANEOUS

48. *a*) Given a soluble oxide, how could you determine whether or not it was the oxide of a metal?

b) What three tests could you make to distinguish between sodium chloride and finely divided paraffin?

c) Define the term "radical," and illustrate by an example.

d) Illustrate the law of multiple proportions by considering the composition by weight of two compounds containing the same elements.

49. *a*) Name each of the following compounds:—the potassium salt of chlorplatinic acid, the sodium salt of tellurous acid, a compound containing magnesium and silicon only, the salt obtained by replacing half the hydrogen of carbonic acid with sodium.

b) If the percentages of calcium in two samples of limestone are 40 per cent and 38 per cent respectively, what conclusion should you draw in regard to the specimens? State the law upon which your conclusion is based. (Atomic weights:—Ca 40, O 16, C 12.)

c) A body of air at constant pressure occupies a volume of 500 c.c. at 20° C. At what temperature will its volume become 1,000 c.c.?

50. *a*) Show briefly the relation of four constituents of the atmosphere to the vital processes of plants and of animals.

b) Describe the chemical changes that occur in a blast-furnace for making pig-iron from an ore consisting of ferric oxide and sand.

51. *a*) State the physical and chemical characteristics of chlorine, bromine, and iodine as regards:—physical

state, color, solubility, tendency to combine with hydrogen.

b) How may bleaching powder be made? What are its properties?

52. *a*) State what you would do in each of the following emergencies respectively:—

1) Chlorine inhaled.

2) Acid in the eye.

3) Oil burning on the floor or desk.

b) Distinguish between destructive, fractional, and ordinary distillation by giving a practical example of each.

53. *a*) Name two metals, each of which yields two oxides, and give the formulas of the oxides.

b) Mention two elements that occur in allotropic forms, and name several allotropic forms in each case.

c) Mention three metals fusible below red heat, and three fusible only above red heat.

d) Mention three gases which are easily liquefied, and three which are liquefied with difficulty.

e) Name an acid all of whose normal salts are soluble in water.

54. *a*) Classify as oxidizing or reducing agents the following substances:—hot concentrated H_2SO_4, H_2S, HOCl, H_2SO_3, concentrated HNO_3.

b) Make three pairs by combinations of the above which will react with each other to form new substances.

55. *a*) What component do rice, tapioca, and potatoes have in common? How could this component be identified?

b) What are the products of the fermentation of glucose? Why do the bubbles of gas not appear at once in this fermentation?

c) Describe the preparation of water gas and write an equation for the reaction involved.

COMPREHENSIVE EXAMINATION QUESTIONS
1916–1920

Group I

CHEMICAL EQUATIONS AND REACTIONS

1. Write equations for *any five* of the following reactions, using formulas throughout: (The equations must be properly balanced to receive credit.)
   a) Solid sodium nitrate heated with solid ammonium chloride = ?
   b) Hydrogen sulfide and ammonia = ?
   c) Phosphoric acid and aluminium hydroxide = ?
   d) Sodium iodide and chlorine = ?
   e) Zinc oxide heated with hydrogen sulfide = ?
   f) Sodium acid carbonate and calcium hydroxide = ?
2. Discuss concisely the important classes of compounds—acids, bases, and salts—from the standpoint of:—*a*) their composition, *b*) their preparation, *c*) their properties. Illustrate your answer fully with formulas and with equations for reactions.
3. Give the formulas of two oxides of sulfur, one oxide of nitrogen, and one oxide of carbon, that are acid anhydrides. Show by equations how an acid may be made from each of these, and give the name of the acid in each case.
4. *a*) Give an example of a chemical change brought about by heat, another by light, and a third by electricity. Mention three chemical reactions the first of which produces heat, the second light, and the third electricity.
   b) Distinguish between exothermic and endothermic reactions and illustrate each by means of an example.
5. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:—

a) Calcium hydroxide and sulfurous acid = ?
b) Steam and magnesium (heated) = ?
c) Hydrogen sulfide burned in excess of oxygen = ?
d) Nitric acid and ammonia gas = ?
e) Aluminium sulfate and ammonium hydroxide = ?

6. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:—
   a) Sodium acid carbonate + hydrochloric acid = ?
   b) Calcium phosphate + sulfuric acid (in excess) = ?
   c) Copper + nitric acid (dilute) = ?
   d) Ferric nitrate + ammonium hydroxide = ?
   e) Silica + sodium carbonate (fused) = ?
7. Carbon dioxide gas in excess is passed into a water solution of sodium carbonate. Write an equation to express the chemical change which takes place. The resulting solution is boiled vigorously for some time. Write an equation to represent the reaction and name the substance which is left in the solution. Explain why these reactions proceed in opposite directions.
8. Write equations for *any five* of the following reactions, using formulas throughout:— (The equations must be properly balanced to receive credit.)
   a) Iron and dilute sulfuric acid = ?
   b) Lead acetate and hydrochloric acid = ?
   c) Aluminium hydroxide and sulfuric acid = ?
   d) Ferrous chloride and chlorine water = ?
   e) Copper sulfate and barium hydroxide = ?
   f) Manganese dioxide and concentrated hydrochloric acid = ?
9. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:—
   a) Lead nitrate and hydrogen sulfide = ?
   b) Copper and sulfuric acid (hot, concentrated) = ?
   c) Phosphoric acid and barium hydroxide = ?
   d) Sodium carbonate and acetic acid = ?

e) Ammonium chloride and calcium hydroxide = ?

10. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:—

a) Nitric acid on ammonium carbonate = ?

b) Silver nitrate solution and magnesium chloride solution = ?

c) Hydrochloric acid and oxygen (with a catalytic agent) = ?

d) Calcium phosphate and sulfuric acid = ?

e) Hydrogen sulfide on lead nitrate solution = ?

11. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit. Indicate by reversed arrows those reactions which do not go almost to completion:—

a) Silver + hot concentrated sulfuric acid = ? (sulfur dioxide is formed).

b) Ammonium sulfate heated with sodium chloride = ?

c) Carbon disulfide burned in an excess of oxygen = ?

d) Sodium chloride, carbon dioxide, ammonia, and water = ?

e) Hydrogen + nitrogen, heated with a catalyzer = ?

12. *a*) Write equations illustrating three different methods for making sodium sulfate.

b) Select any two of these equations and tell why the reaction goes to completion in each case.

13. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:—

a) Ethyl alcohol burned completely in oxygen = ?

b) Hydrogen sulfide + chlorine (in solution) = ?

c) Silver nitrate + calcium chloride = ?

d) Nitric oxide + oxygen gas = ?

e) Ferric chloride + sulfuric acid (concentrated) = ?

14. Write equations for the following reactions, using formulas throughout. The equations must be properly balanced to receive credit:—
   a) Sodium chloride + manganese dioxide + concentrated sulfuric acid = ?
   b) Ferric chloride + calcium hydroxide = ?
   c) Lead nitrate + hydrogen sulfide (solutions) = ?
   d) Ammonium sulfate + sodium hydroxide = ?
   e) Concentrated nitric acid heated = ?

Group II

LABORATORY METHODS

15. *a*) How can decomposed organic matter be removed from water without distillation?
   b) How can bacteria in drinking-water be destroyed without raising its temperature?
   c) How can temporary hardness in water be removed without raising its temperature?
   d) How can water be freed from dissolved ammonia?
16. What experiment would demonstrate that *a*) silver nitrate contains a metal? *b*) sodium carbonate is a salt? *c*) bromine is more active chemically than iodine but less so than chlorine? *d*) iron is a reducing agent? *e*) chlorine bleaches only indirectly?
17. *a*) State how you would prove whether a certain salt solution is unsaturated, saturated, or supersaturated? *b*) How do changes in temperature and pressure respectively change the solubility in liquids of gases and of solids?
18. Chlorine and nitric acid often act as oxidizing agents, sulfur dioxide and carbon as reducing agents. Explain these statements and give examples, with equations, illustrating these actions. State any necessary conditions of dilution or of temperature.
19. *a*) How would you proceed in order to get large crystals from a solution? Small ones?

b) Why do certain crystalline substances on exposure to the air crumble while others do not?

20. *a*) What takes place when steam is passed over heated zinc or iron?

b) How would you identify the products?

c) What do you learn about the composition of water from this experiment?

21. Give a detailed account of a good laboratory method for preparing and collecting chlorine in quantity; write the chemical equations involved; make a diagram of the apparatus.

22. Give two different general methods for the formation of an acid. Illustrate each by an example giving equations for the reactions involved. Are there analogous methods for the formation of bases? Illustrate by equations.

b) Sodium sulfate and copper sulfate are dissolved in separate portions of pure water. Do the two solutions affect litmus alike? Explain.

23. *a*) Mention three methods of increasing the speed of a reaction and give a practical illustration of the application of each method.

b) If sodium is exposed to air, what product is finally obtained? How is sodium usually preserved in the laboratory or stockroom?

24. *a*) Why is sulfuric rather than hydrochloric acid used in making nitric acid?

b) Why is hydrochloric rather than nitric acid used in making hydrogen sulfide?

c) Why is hydrochloric rather than sulfuric acid used in making carbon dioxide from marble?

d) Why is sulfuric rather than hydrochloric acid used in preparing oxygen from water by electrolysis?

e) Why is nitric rather than hydrochloric acid used to dissolve a silver coin?

f) Why is dilute rather than concentrated sulfuric acid used in making hydrogen?

25. *a*) What particular properties are used in recovering the sulfur from a solution in carbon disulfide?
b) What chemical tests are used in recognizing sulfuric acid? a chloride? nitrous oxide?
26. How could you obtain *a*) sulfur from hydrogen sulfide, *b*) metallic copper from copper oxide, *c*) potassium nitrate crystals from potassium chloride, *d*) ferric oxide from ferric chloride?
27. Tell how you would determine experimentally *a*) either the equivalent of some element or the molecular weight of some gas: *b*) either the percentage of carbon dioxide in exhaled air or of oxygen in ordinary air. Indicate the method of computing the result in each case.
28. State the reason for each of the following precautions:—
a) Potassium chlorate and manganese dioxide, for making oxygen, must not be ground too finely together.
b) A hot object should be cooled before weighing.
c) Concentrated solutions of acid and alkali should not be mixed without previous dilution.
d) Phosphorus should not be handled with the fingers.
29. *a*) Outline a simple process for making soap and explain the chemical reaction which takes place in its formation (without equation).
b) Account for the action upon litmus paper of a solution of a soap which contains no free alkali.
30. *a*) How would you determine whether a given sample of ammonia gas contained air?
b) Give tests for free chlorine, bromine, and iodine respectively; give also a test for the ions of the same elements.
31. *a*) Name and describe three allotropic forms of sulfur, and tell how each is prepared.
b) Give the names and formulas of the two most important oxides of sulfur, and show by means of

chemical equations what occurs when each of these oxides is treated with water.

32. State in words and by writing equations how you would obtain:—*a*) Ferric chloride from ferrous chloride; *b*) ferrous chloride from ferric chloride; *c*) sodium carbonate from sodium hydroxide; *d*) sodium hydroxide from sodium carbonate; *e*) oxygen from ozone; *f*) ozone from oxygen.

33. *a)* Describe the laboratory preparation of ammonia and mention its most important properties.

b) How can ammonia be made commercially from the elements?

c) In what way can ammonia be used in the manufacture of explosives?

34. The water solutions of certain substances give the following tests:—What may be the dissolved substance in each case?

a) The solution turns blue litmus red and forms with silver nitrate solution a white precipitate insoluble in nitric acid.

b) The solution gives a deep-red color with ammonium or potassium thiocyanate (NH_4CNS or $KCNS$), and with barium chloride solution a white precipitate insoluble in hydrochloric acid.

c) The solution gives a blue coloration with iodine.

d) The solution colors the Bunsen flame violet and forms a brown ring when it is mixed with concentrated sulfuric acid and ferrous sulfate solution is added.

e) The solution colors the Bunsen flame yellow and turns red litmus blue.

35. How would you prove, by chemical means, the presence in air of each of the following components:—*a*) water, *b*) carbon dioxide, *c*) oxygen, *d*) nitrogen?

36. *a*) Why does wood burn with a flame while charcoal merely glows?

b) Can you light a jet of oxygen in an atmosphere of 1) air, 2) hydrogen? Explain.

c) Describe and explain the successive effects observed

when a thin strip of copper is passed very slowly through a Bunsen flame.

37. What experiment would you make to distinguish between:—
    a) Sodium chloride and ammonium chloride?
    b) Potassium iodide and potassium bromide?
    c) Glucose and cane sugar?
    d) Copper oxide and manganese dioxide?
    e) Chlorine water and bromine water?

38. *a*) A small flask contains ferric chloride (yellow) strongly acidified with hydrochloric acid. A quantity of iron tacks is added and the flask is closed in such a manner as to permit the escape of gas and to prevent the entrance of air. How do you explain the loss of color? Write an equation for the reaction.
    b) On exposure to air the yellow color of the solution is gradually restored. Account for the result. Write an equation for the reaction.

39. *a*) What is a saturated solution of a solid in a liquid?
    b) How does increasing the temperature affect the solubility of solids in liquids?
    c) In what two ways could a saturated solution of sodium chloride in water be prepared? How could you satisfy yourself that the solution is just saturated in both cases?

40. *a*) Given pure samples of sodium carbonate, chloride, nitrate, sulfide, and sulfate, give one test by which the negative (acid) radical in each may be identified.
    b) Write equations for the reaction of each of the above substances with concentrated sulfuric acid at room temperature.

41. Explain each of the following experimental facts:—
    a) A dilute solution of potassium chloride has a lower freezing-point than one of sugar of the same concentration measured in gram molecules per liter.
    b) A drop of concentrated sulfuric acid on a wooden table makes a black spot.

c) Many minute gas bubbles appear on the inside of a glass of cold water standing in a warm room.

d) Copper does not liberate hydrogen from nitric acid.

e) Concentrated hydrochloric acid, if added to a saturated solution of sodium chloride, gives a white precipitate.

42. *a*) Describe briefly an experiment to determine the percentage of oxygen in air. *b*) State as fully as possible the composition of air. *c*) Give three proofs that air is a mixture and not a compound.

43. *a*) Given unlabeled bottles which severally contain hydrochloric acid, nitric acid, and sulfuric acid, how would you identify each, using a chemical test in each case?

b) Give one test by which you would determine in each case whether the acid is dilute or concentrated.

44. *a*) Name and define four different types of chemical action, and illustrate each by an experiment which you have performed in the laboratory, stating the object of the experiment, together with the names of the substances used and of the products formed.

b) What is meant by a radical? Give an example to show how a radical may be decomposed in a chemical change.

45. Two rods of copper are placed in a solution of copper sulfate. What takes place when a current of electricity is passed from one rod to the other through the solution? How might you prove what happens to each of the copper rods?

46. *a*) Describe a test or tests to distinguish 1) between oxygen and nitrous oxide, 2) between hydrogen and carbon monoxide, 3) between nitrogen and carbon dioxide.

b) State briefly the effect of inhaling each of these gases in the pure state.

47. *a*) Outline three different methods for obtaining oxygen; give some idea of their relative cost.

b) Write equations, using formulas, to show how each of three metals may be obtained from ores or artificial compounds. Each method involved should be different from the others.

48. How may ozone be prepared? What are its properties?

    How is its formula written? How would you demonstrate its chemical composition (not its formula)?

49. How would you determine by chemical tests whether *a*) "woolen" goods contained cotton, b) baking powder contained ammonium compounds, *c*) water contained chlorides?

50. Describe the action, if any, and represent by equations the chemical changes taking place when dilute hydrochloric acid and nitric acid are added separately to each of the following substances:—*a*) ferric hydroxide, *b*) zinc oxide, *c*) calcium carbonate, *d*) silver.

Group III

COMMERCIAL APPLICATIONS

51. Name or describe one useful property of each of the following substances, and give one use made of it because of this property:—slaked lime, distilled water, charcoal, sulfur dioxide, aluminium, sodium nitrate, cast iron, copper sulfate, coke, lead.

52. State one practical use for each of the following substances, suggested by the property mentioned. Give in each case an example of such a substance. *a*) A metal having a very high melting-point, *b*) a substance from which a water solution having a very low freezing-point may be made, *c*) an acid having a high boiling-point, *d*) a solid or liquid capable of sudden conversion into gases at high temperature, *e*) a volatile, non-inflammable liquid.

53. *a*) State the composition of two kinds of baking powder.

b) Write an equation for the reaction which occurs when one of these powders is moistened with water.

c) Explain the action of yeast in bread-making.

54. Give the names and formulas of five common minerals of industrial importance. State what commercial use may be made of each of them.

55. *a*) Mention two compounds of nitrogen that are used as fertilizers.

b) What natural provision is there for converting the nitrogen of the air into plant food?

c) Outline one artificial process for the fixation of atmospheric nitrogen.

56. *a*) What danger is there in a long-continued scarcity of potassium compounds? Why has there recently been such a scarcity in this country?

b) Make a list of the sources of potassium compounds. Suggest a method for extracting a potassium compound from two of the raw materials mentioned.

57. Discuss *a*) the extraction of sulfur in the United States and abroad; *b*) its physical and chemical properties; *c*) its uses.

58. Answer any two of the following questions:—

a) Mention a necessary property that must be possessed by an oil 1) for soap-making, 2) for mixing with paint, 3) for a lubricant. Name as an example some particular oil for each use.

b) What are the physical and chemical differences between cast iron and steel?

c) Why does iron, in the course of time, turn completely into rust, while aluminium and zinc tarnish only slightly?

59. *a*) Describe the production of ammonia either by the Haber process, or from calcium cyanamide. (All equations are required.)

b) Write down in parallel columns five specific physical properties of ammonia, and three specific chemical properties.

60. Describe the manufacture of *any one* of the following substances, giving a diagram, and equations whenever possible:—*a*) Ethyl alcohol; *b*) water gas; *c*) open-hearth steel.

61. *a*) Distinguish between chemically pure water and spring water. *b*) How may water be purified on a small scale for household use? How is it purified on a large scale for a city supply? *c*) Name one impurity which renders water unfit for use in laundries and outline a practical method for removing it.

62. Describe two important chemical industries depending directly or indirectly on electrical energy.

63. *a*) Outline the manufacture of sulfuric acid by the contact process.

b) Indicate the importance of this acid in the manufacture of military explosives by citing two processes in which it is necessary.

64. *a*) What is "sterling" silver, and what acid should be used to dissolve it? *b*) How may pure silver be obtained from this solution? *c*) State how articles of baser metal are plated with silver, and how mirrors are silvered. *d*) What compound of silver is used in indelible ink? Explain the chemical changes involved in its use.

65. *a*) Name three military explosives and state from what substances each is made.

b) To what element does each of these owe its explosive character?

c) State briefly how two of the following substances are made:—1) Celluloid; 2) mercerized cotton; 3) collodion; 4) artificial silk.

66. *a*) In the smelting of iron ore, what materials enter the blast furnace, and what is the function of each?

b) What name is given to the metal produced by the blast furnace, and how does it differ in physical properties and in chemical composition from the product of the Bessemer converter?

67. *a*) What property has helium which makes it better than hydrogen for filling balloons?

b) How does commercial copper compare in purity with other metals as commercially supplied? Describe briefly the refining of copper.

c) Mention three substances commonly used for extinguishing fire. Indicate the one that you consider best adapted to extinguishing burning gasoline.

68. Why should sulfur compounds be removed from illuminating gas? phosphorus from steel? dust from sulfur dioxide in the contact process for making sulfuric acid? moisture from materials for making baking powders? calcium and magnesium chlorides from table salt?

69. Outline one practical method for the preparation of each of the following substances:—*a*) nitrogen from the air, *b*) carbon monoxide, *c*) calcium oxide, *d*) glucose. Mention one industrial use for each of the above-mentioned substances.

70. Discuss sulfuric acid with reference to:—

a) Its physical and chemical properties.

b) Four of its important uses.

c) One process of manufacture.

71. *a*) State the action of yeast on sugar.

b) Describe the function of baking powder in cooking.

c) Give one process for softening hard water.

d) Why does the flame of a gas stove sometimes "strike back"? How can this difficulty be remedied?

72. *a*) How may crude copper be refined? *b*) State the physical and chemical properties of copper. Write an equation showing the action of hot, concentrated sulfuric acid upon the metal. *c*) Name the elements present in important alloys of copper.

73. *a*) Describe the manufacture of sulfuric acid by the contact process.

b) Show how sulfuric acid is used to produce another acid, and state the principle involved.

c) Write the ionic equation for neutralizing barium hydroxide with sulfuric acid.

74. *a*) Outline a commercial method for producing metallic aluminium. *b*) How is aluminium used to produce other metals from their oxides? *c*) Explain the fact that aluminium retains its bright appearance in the air. *d*) Mention one industrial use for alum.

75. *a*) Outline a method for the manufacture of nitric acid from atmospheric nitrogen or from ammonia. *b*) Enumerate at least two of the important commercial uses of nitric acid.

76. *a*) Name three classes of food substances and list several food substances which are typical in each class.
b) Describe tests by which the nature of a simple food substance may be determined.

77. *a*) Describe the "burning" of limestone. Make a diagram of a kiln, and indicate its operation.
b) Distinguish between quicklime, slaked lime, air-slaked lime, lime water, and milk of lime.
c) What is meant by "destructive distillation"? By applying this process to soft coal, what products are obtained? What products are obtained by applying the process to wood?

78. *a*) Name and describe one important commercial process for manufacturing sodium carbonate, giving all the equations involved.
b) How may sodium acid carbonate be distinguished from sodium carbonate?

79. *a*) Give the names and formulas of two alcohols, together with the name and formula of the acid derived from each.
b) Outline a process for the commercial production of grain alcohol and state some of its industrial uses. What is denatured alcohol?

PROBLEMS

80. A certain quantity of magnesium dissolved in acid gave exactly 100 c.c. of dry hydrogen at a temperature of 22° C. and a pressure of 780 m.m. How many grams of metal were used? Compute the result to three significant figures (Mg = 24.3).

NOTE:—A liter of hydrogen at 0° C. and 760 m.m. weighs 0.09 g.

81. *a*) What is a normal solution of an acid? of an alkali?
b) 10 c.c. of ordinary household ammonia are neutralized by the addition of 40 c.c. of a normal solution of hydrochloric acid. What weight of ammonia gas, NH_3, is contained in each cubic centimeter of the original solution?

82. At standard temperature and pressure, one liter of the gaseous element, *A*, unites with three liters of the gaseous element, *B*, to make two liters of the gas, *C*. If each molecule of *C* contains one atom of *A*, what is the simplest formula for a molecule of the element *A*? Show clearly how you arrive at your conclusion.

83. *a*) A certain weight of potassium carbonate, heated with 10 grams of sand, gives 25.6 grams of potassium silicate according to the equation $K_2CO_3 + SiO_2 = K_2SiO_3 + CO_2$. Calculate the weight of the potassium carbonate. (K 39, Si 28, O 16, C 12.)
b) What is the percentage of sulfur trioxide in white vitriol ($ZnSO_4 \cdot 7H_2O$)? (Zn 65, S 32, O 16, H 1.)

84. A portable gas stove used in heating a room burns natural gas (assumed to be pure methane, CH_4) and consumes in one hour 10 cubic feet of gas measured at a pressure of 30 inches of mercury and at a temperature of 60° F. What volume of oxygen is consumed and what space is occupied by the carbon dioxide which is produced, when measured under conditions of pressure and temperature previously speci-

fied? If 1 cubic foot of methane under these conditions weighs 0.04225 lbs., what weight of water vapor is formed during the combustion? (O 16, C 12, H 1.)

85. *a*) Fifty cubic centimeters of a solution containing 40 grams of sodium hydroxide per liter neutralize 40 c.c. of a solution of hydrochloric acid. What is the concentration of the acid solution in grams per liter? (Cl 35.5, Na 23, O 16, H 1.)

b) How many grams of potash alum ($K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24\,H_2O$) can be made from 69 grams of bauxite ($Al_2O_3 \cdot 2\,H_2O$)? (K 39, S 32, Al 27, O 16, H 1.)

86. A liter of a certain elementary gas weighs 7.50 grams, while a liter of hydrogen gas under the same conditions weighs 0.050 gram. The atomic weight of the element composing the gas is 75. How many atoms are there in one molecule of the gas?

87. Two gram molecules of the oxide RO combine with 44.8 liters of oxygen at 0° and 380 m.m. pressure. The volume of the product, under the same conditions, is nearly equal to that of the oxygen taken. Calculate the formula of the product.

88. Baking powder can be made by mixing baking soda, $NaHCO_3$, and cream of tartar, $HKC_4H_4O_6$. These substances react according to the following equation:—

$$NaHCO_3 + HKC_4H_4O_6 = H_2O + CO_2 + NaKC_4H_4O_6.$$

a) How much cream of tartar should be mixed with one kilogram of baking soda so that neither ingredient will be in excess?

b) What volume of carbon dioxide at 0° C. and 760 m.m. may be obtained from the baking powder thus made? (K 39, Na 23, O 16, C 12, H 1.)

NOTE:—One liter of CO_2 at 0° C and 760 m.m. weighs 1.98 grams.

89. Five liters of carbon monoxide are mixed with just enough oxygen for complete combustion and the mixture is ignited. If the original gases are measured at 20° C., at what temperature will the product occupy the same volume, the pressure remaining the same?

90. Calculate the molecular weight of carbon-dioxide gas from the following data, showing clearly every step of the calculation:—

Weight of flask filled with CO_2, dry = 102.38 grams
Weight of flask filled with air, dry = 101.56 grams
Temperature of measured gases = 0° C.
Pressure of measured gases = 770 m.m.
Volume of flask = 1200 c.c.

NOTE:—One liter of air at 0° C. and 760 m.m. weighs 1.29 grams.

91. *a*) Give directions for making a normal solution of sulfuric acid and one of sodium hydroxide.

b) Ten cubic centimeters of a normal solution of sulfuric acid requires 2.5 c.c. of a solution of sodium hydroxide for complete neutralization. Find the concentration of the solution of sodium hydroxide in grams per liter. (S 32, Na 23, O 16, H 1.)

92. *a*) How many cubic centimeters of carbon dioxide, CO_2, measured at 0° and 760 m.m., will be absorbed by a solution containing 2 grams of sodium hydroxide, to form sodium carbonate and water? (Na 23, O 16, C 12, H 1.)

NOTE:—One liter of carbon dioxide at 0° C. and 760 m.m. weighs 1.98 grams.

b) The formula of a gaseous compound is C_2H_2. Calculate its percentage composition and its vapor density.

93. One hundred liters of dry air at 20° C. and at 760 m.m. contain 0.078 gram of carbon dioxide. What is the proportion by volume of carbon dioxide present in the air?

NOTE:—One liter of carbon dioxide at 0° C. and 760 m.m. weighs 1.98 grams.

94. Two grams of finely divided metallic nickel are heated with a quantity of sulfur slightly in excess of that needed for complete combination until the chemical action is completed and the excess of sulfur is vaporized. The weight of the product formed is 3.09 grams.

Give the name of the product, find its percentage composition and also the simplest formula by which its composition may be expressed. (Ni = 58.7, S = 32.)

95. *a*) How many cubic centimeters of oxygen, measured at 0° C. and 760 m.m. can be obtained by the complete decomposition of one kilogram of 3 per cent solution of hydrogen peroxide, H_2O_2, into water and oxygen? (H 1, O 16.)

NOTE:—A liter of oxygen at 0° and 760 m.m. weighs 1.43 grams.

b) What is the percentage of silica, SiO_2, in the mineral analcite, $Na_2SiO_3 \cdot Al_2(SiO_3)_3 \cdot 2H_2O$? (Si 28, Al 27, Na 23, O 16, H 1.)

96. 1.0085 grams of pure tin foil were oxidized with nitric acid, and the final weight of the highly ignited oxide was 1.2790 grams. From the data submitted, find the percentage composition and the simplest formula of this oxide of tin. (Sn = 119, 0 = 16.)

97. 1.8 grams of magnesium displace from acid 1820 c.c. of hydrogen, measured dry at 740 m.m. pressure and 20° C. Find the volume of this gas under standard conditions and determine the valence of magnesium. (Mg. = 24.3, H = 1.008.) What is your definition of valence?

NOTE:—The weight of one liter of hydrogen under standard conditions is 0.09 gram.

98. How many liters of ammonia gas, measured under standard conditions, can be obtained when 20 gm. of sodium hydroxide react with an excess of ammonium sulfate? (Na = 23, O = 16, H = 1, N = 14, S = 32.)

NOTE:—A liter of ammonia gas at 0° C. and 760 m.m. weighs 0.772 g.

99. *a*) How many grams of hydrochloric acid gas can be obtained by heating ten grams of crystallized ferric chloride, $FeCl_3 \cdot 6H_2O$, with concentrated sulfuric acid? (H = 1, O = 16, Cl = 35.5, Fe = 56.)

b) What is the percentage of sulfur in iron alum, $K_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 24H_2O$? (K = 39, S = 32, O = 16, Fe = 56, H = 1.)

100. *a*) Calculate the percentage of oxygen in crystallized copper nitrate, $Cu(NO_3)_2 \cdot 6H_2O$. (Cu = 64, N = 14, O = 16, H = 1.)

b) What weight, and volume at 0° C. and 760 m.m., of carbon dioxide can be obtained by treating an excess of sodium acid carbonate with 490 g. of sulfuric acid containing 20 per cent of H_2SO_4? (Na = 23, C = 12, O = 16, H = 1, S = 32.)

NOTE:—A liter of carbon dioxide at 0° C. and 760 m.m. weighs 1.97 gm.

101. *a*) Calculate the weight of manganese dioxide required to produce chlorine enough to fill a flask of 4 liters capacity when the barometer stands at 760 m.m. and the temperature is 0° C. (Mn. = 54.9, O = 16, Cl = 35.5.)

NOTE:—A liter of chlorine at 0° C. and 760 m.m. weighs 3.22 grams.

b) What weight of manganese dioxide would be required if the flask were filled at 760 m.m. and 273° C.?

102. 10 grams of crystallized ammonium carbonate, $(NH_4)_2CO_3 \cdot H_2O$, are heated until completely decomposed into ammonia, carbon dioxide, and steam. What will be the total volume of these products at 273° C. and 760 m.m. pressure? (O = 16, N = 14, C = 12, H = 1.)

NOTE:—Under the conditions above, liter volumes of ammonia, carbon dioxide, and steam weigh 0.38 gram, 0.98 gram, and 0.40 gram, respectively.

103. A balloon requires for adequate inflation 5,000 gram-molecular volumes (or an equal number of gram-molecules) of hydrogen, measured at normal temperature and pressure. What is the cost of inflating such a balloon if scrap iron at 1 cent per kilogram and sulfuric acid, containing 20 per cent of H_2SO_4, at

4 cents per kilogram, are used for generating the hydrogen? (Fe = 56, H = 1, S = 32, O = 16.)

104. A certain chemical compound is found by analysis to contain 92.3 per cent of carbon and 7.7 per cent of hydrogen. What is the simplest formula which can express its composition? If the molecular weight is 78, what is the formula? (C = 12, H = 1.)

105. *a*) What volume would be occupied by 14 grams of carbon monoxide under standard conditions? (O = 16, C = 12.)

b) If ten liters of carbon monoxide under standard conditions are heated to 27.3° C., without change in pressure, what volume will the gas occupy?

c) What volume of oxygen is necessary to combine with five liters of carbon monoxide under the same conditions of temperature and pressure? Show how you arrive at your conclusion.

106. *a*) A compound has the following composition:— carbon, 54.67 per cent; hydrogen, 9.11 per cent; oxygen, 36.22 per cent. Find the simplest formula for the substance. (C = 12, O = 16, H = 1.)

b) A body of air at constant pressure occupies a volume of 500 c.c. at 20° C. At what temperature will its volume become 1,000 c.c.?

107. One gram of pure iron forms 1.43 g. of an oxide. Find *a*) the percentage composition for this oxide of iron, *b*) its simplest formula, and *c*) the equivalent weight of iron in the compound. (Fe = 56, O = 16.)

Group V

Chemical Laws, Theories, and Definitions

108. Define, and give at least one example of 1) diacid base, 2) acid salt, 3) reducing agent, 4) anion, 5) atom, 6) molecule.

109. *a*) What is the relation between volume and pressure of a gas when the temperature is constant? between

volume and temperature when the pressure is constant? between temperature and pressure when volume is constant?

b) From the standpoint of the molecular hypothesis explain the fact that 1) 40 gallons of oxygen may be forced into a small steel cylinder, 2) gas escapes from a glass of soda water, 3) chlorine gas, although heavier than air, escapes from an upright vessel.

110. Classify in natural groups the following elements:—carbon, calcium, chlorine, barium, bromine, iodine, and silicon. Indicate the relations of those within each group by comparing the formulas and the properties of their oxides or hydrides or both.

111. Define and illustrate with an example each of the following:—*a*) acid anhydride, *b*) catalytic agent, *c*) saturated solution, *d*) sublimation, *e*) either destructive distillation or fractional distillation.

112. *a*) State one point of resemblance and one point of difference between solutions and compounds.

b) Define precipitation and crystallization; illustrate each by means of an example.

c) How are the freezing-point and the boiling-point of a solvent affected by dissolved substances? Give a practical application of one of these facts.

113. *a*) What do the following terminations indicate, *-ite, -ic, -ide, -ate, -ous?*

b) What relation does the combining weight of an element bear to its atomic weight?

114. *a*) If steam is passed over heated iron, iron oxide and hydrogen are formed; if hydrogen is passed over heated iron oxide, metallic iron and steam are formed. Why are the products of reaction different in the two cases?

b) Under what conditions will a chemical reaction reach equilibrium? Under what conditions will it run to an end?

115. *a*) Give a concise statement of the constitution of matter according to the atomic theory.

b) State any two laws fundamental to the theory, and show how this theory explains these laws.

116. *a*) Arrange the names of ten common elements in natural groups.

b) Write the formula for one oxide of each and state what acid or base can be formed from each of these oxides.

117. Define, and also illustrate by means of at least one example in each case, the following terms:—*a*) element; *b*) synthesis; *c*) cation; *d*) catalyzer; *e*) hydrolysis.

118. Indicate the difference in meaning between *a*) ion and radical, *b*) electrolysis and ionization, *c*) equivalent and atomic weight of an element, *d*) hydrate and hydroxide, *e*) monobasic and dibasic acid. Give an example of each.

119. Which is the more specific term of the following pairs:—*a*) dissociation or ionization, *b*) carbohydrates or sugars, *c*) fermentation or decomposition, *d*) halogen acids or binary acids? Considering each of the foregoing pairs separately, cite a particular case illustrating the more general term which is not included by the more specific.

120. Define the term "molecular weight," and give one method for determining a molecular weight.

121. *a*) Assume X to be a gaseous element having a valence of three and containing two atoms per molecule. To make two volumes of its gaseous compound with hydrogen, how many volumes of each constituent are required? State the law upon which your conclusion is based.

b) From the standpoint of the electrolytic dissociation theory, what takes place when dilute solutions of an acid and a base are mixed?

122. *a*) Distinguish between a chemical law and a chemical theory.

b) Name three laws dealing with weights; three dealing with gases.

c) Name two important theories in chemistry.

123. Barium carbonate is treated with a quantity of boiling dilute sulfuric acid just sufficient for complete reaction. Using the language and symbols of the ionization theory wherever pertinent, describe what takes place.

124. Define and give an example of *a*) catalysis, *b*) equivalent of an element, *c*) allotropy, *d*) molecular weight, *e*) carbohydrate.

125. *a*) State the Law of Multiple Proportions.
b) Give two substances to illustrate the above law with the percentage composition in each case.

126. Give *a*) exact statement, *b*) experimental proof, and *c*) a practical application of one of the fundamental laws of chemistry.

127. What experimental evidence can be cited to show *a*) that chloride ions are not molecules of chlorine? *b*) that chloride ions are charged with negative electricity?

128. *a*) What is an electrolyte? Distinguish between electrolysis and electrolytic dissociation.
b) If a strong (active) acid is added to the salt of a weak acid in water solution, what becomes of the four different ions involved? Illustrate by an example.

129. *a*) Define the terms hydroxide, anhydrous, and water of hydration (crystallization).
b) Show that hydration is a reversible reaction by discussing the commercial manufacture and use of plaster of Paris.

130. *a*) Using the ionization theory, explain the equilibrium in a dilute solution of sodium chloride. If two platinum electrodes are introduced and a current of electricity passed, explain in detail the changes at the cathode.
b) Compare the degree of ionization of 1) hydrochloric acid and acetic acid, 2) ammonium hydroxide and potassium hydroxide, in water solutions of the same concentration.

131. State Avogadro's law and show in detail how this law guides the chemist in determining the molecular weights of gases or vapors.

132. *a*) Define the terms "molecule," "atom," and "ion."
b) State Avogadro's hypothesis, and show how it guides the chemist in determining molecular weights.

133. *a*) State the Law of Multiple Proportions, and illustrate it by the consideration of two compounds of carbon and hydrogen containing respectively 75 per cent and 92.3 per cent of carbon.
b) How does this law support the hypothesis that the elements are composed of atoms having definite weights?

134. *a*) Mention three important differences between the water solutions of electrolytes and those of non-electrolytes. How are these differences explained?
b) Explain fully in terms of the ionization theory the electrolysis of a solution of copper sulfate.

135. Write a reversible chemical reaction and explain how it may be made to go to completion in either direction.

136. *a*) State Gay-Lussac's law of combining gas volumes, and illustrate with an example. State the hypothesis which serves to explain the facts generalized by this law.
b) 30 grams of chlorine are to be united with hydrogen. What volume of hydrogen is required at 0° C. and 760 m.m., and what volume of hydrogen chloride results under the same conditions? (Cl = 35.5, H = 1.)

NOTE:—A liter of chlorine at 0° C. and 760 m.m. weighs 3.22 grams, and a liter of hydrogen 0.09 gram.

137. *a*) Define and give three examples, of neutralization, describing the ionic changes involved in the reactions.
b) Define and give an example of hydrolysis. How can the litmus reaction of the water solution of a normal salt be predicted from its composition? Illus-

trate your answer by an example of a salt having an acid reaction and of another having a basic reaction.

Group VI

MISCELLANEOUS

138. Indicate the basic oxides in the following list, and write the names of the compounds formed by heating them with the acid anhydrides in the list: phosphorus pentoxide, calcium oxide, silicon dioxide, sulfur trioxide, and aluminium oxide.

139. Give the method of keeping and the necessary precautions in the storage of each of the following substances:—*a*) sodium, *b*) gasoline, *c*) yellow (white) phosphorus, *d*) bromine, *e*) hydrofluoric acid.

140. Answer any two of the following questions:—

a) Why does a water solution of ferric chloride give an acid reaction, while one of sodium carbonate gives an alkaline reaction?

b) Account for the fact that a solution of common salt in water conducts the electric current, while one of sugar does not.

c) Which exhibits the greater osmotic pressure, a gram-molecular solution of salt or one of cane sugar? Why? Sketch an apparatus for demonstrating osmotic pressure.

141. *a*) Name two elements which are liquid at ordinary temperatures. *b*) Name the common allotropic forms of each of four elements. *c*) Name two elements having exceptionally high melting-points, and state how this property is put to practical use in case of each.

142. Compare and contrast the properties and uses of the two chlorides of mercury. Give the scientific and the common names; also the formulas of these compounds.

143. Make a list of five gases which would be dangerous to

life if contained in air to the extent of a small per cent, and suggest a method of eliminating each gas. Only a single impurity is assumed present in any one of the given samples of air.

144. *a*) Name the products when:—silica is fused with sodium carbonate; when dilute sulfuric acid acts on magnesium.

b) Give two uses for each of the following substances:—ammonium hydroxide, borax.

c) Why is nitric acid a better solvent for silver, lead, and mercury than hydrochloric acid?

145. *a*) Make a diagram of an acetylene generator. With the aid of an equation, explain its operation.

b) Write the equation for the complete combustion of acetylene.

c) Why does acetylene burn with a flame which is more luminous than that of methane?

146. State one locality in which each of the following substances, respectively, is found in relative abundance:—iron ore, diamond, petroleum, sodium nitrate, sulfur, gold, copper ores, phosphate rock, coal, radium compounds.

147. *a*) In what two ways can ammonium chloride, without reacting chemically with any other substance, be split up into two parts? Specify in each case the conditions under which complete recombination will take place.

b) Why is hydrogen more rapidly evolved by zinc reacting with hydrochloric acid than with acetic acid of the same concentration?

148. Classify the following compounds into *a*) acids, *b*) bases, *c)* salts, *d)* acid anhydrides, *e)* substances belonging to none of the foregoing four classifications:—sulfur dioxide, calcium oxide, ammonium carbonate, iron sulfide, sodium hydroxide, phosphorus pentoxide, barium chloride, hydrogen sulfide.

149. Explain each of the following facts:—

a) Painters' rags sometimes take fire spontaneously.

b) Concentrated rather than dilute sulfuric acid is used in making hydrochloric acid.

c) Acetic and nitric acid solutions of the same concentration in gram molecules per liter do not conduct electricity equally well.

d) When the stopper is removed from a bottle containing concentrated hydrochloric acid, white fumes are sometimes observed.

e) A solution of sodium carbonate has an alkaline reaction.

150. *a*) Why does the admission of air at the base of the Bunsen burner make the flame non-luminous?

b) Why is the temperature of a flame of hydrogen burning in oxygen higher than that of hydrogen burning in air?

c) Why is a mixture of fine coal dust and air explosive?

THE UNIVERSITY OF THE STATE OF NEW YORK

214th High School Examination

Thursday, January 20, 1916—9.15 a.m. to 12.15 p.m., only

CHEMISTRY

Write at top of first page of answer paper *a*) name of school where you have studied, *b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Make a diagram of the apparatus used in the laboratory for the preparation and collection of ammonia [2]. Give *two* reasons for the method of collection [2]. Name the materials used and write the equation [2]. Mention an important commercial source of ammonia [2]. Mention *two* properties of the water solution of ammonia that are characteristic of bases [2].
2. How would you proceed to prepare sodium chloride by *a*) neutralization [2], *b*) direct combination [2], *c*) displacement due to volatility [2], *d*) displacement due to insolubility [2]? Mention *two* insoluble sulfates [2].
3. Give a full description of the laboratory method by which the equivalent (combining weight) of a metal may be determined. [10]

Group II

Answer at least one question from this group.

4. What is roll sulfur [2]? How is sulfur obtained from deposits in the United States [2]? Name *two* allotropic forms of sulfur [2]. Define allotropism [2]. Name *two* elements, other than sulfur, that have allotropic forms [2].
5. Tell what is meant by *each* of the following: *a*) saturated solution, *b*) supersaturated solution, *c*) complete ionization, *d*) electrolysis, *e*) heat of neutralization. [10]
6. Give proof *a*) that the air is a mixture rather than a compound [3], *b*) that there are at least *two* atoms in a molecule of hydrogen [3]. State *two* laws used in the proof given [4].

Group III

Answer at least one question from this group.

7. Find the number of liters of hydrogen sulfide that will result from the addition of sufficient hydrochloric acid to 100 grams of ferrous sulfide. [10] (Atomic weights:—S = 32, Fe = 55.8.)
8. Show what will be the relative volumes of the reacting substances in *each* of the following cases:— *a*) one volume of carbon monoxide plus sufficient oxygen burns to carbon dioxide [4], *b*) one volume of marsh gas plus sufficient oxygen burns to carbon dioxide and water [6].
9. Write the equation expressing the reaction between *a*) sulfuric acid and saltpeter, *b*) sodium sulfite and hydrochloric acid, *c*) copper and silver nitrate, *d*) sodium carbonate and aluminum sulfate, *e*) aluminum and sodium hydroxide. [10]

Group IV

Answer at least one question from either this group or group V.

10. Why is 14 carat gold better fitted for use in ornaments than 18 or 22 carat gold [3]? Mention the

constituents of brass [2]. Give *one* use of brass and one use of *each* of the constituents of brass [3]. What element has given most success as filament of electric lights [2]?

11. Describe the process of manufacture of quicklime and that of the manufacture of Portland cement [4]. Compare the hardening of lime mortar with the hardening of cement mortar [4]. How does concrete differ from cement mortar [2]?

12. Describe the contact process of the manufacture of sulfuric acid on a commercial scale [6]. Mention *two* industries that use large quantities of sulfuric acid and give the reasons why it is used in these industries [4].

Group V

Answer at least one question from either this group or group IV.

13. What is a soap [5]? Distinguish *each* of the following kinds of soap from the others:—soft soap, hard soap, floating soap, scouring soap, soap powder [5].

14. What element makes both peas and meats valuable as foods [2]? Give a test to distinguish *a*) wool from cotton [2], *b*) glucose from cane sugar [2]. Name *two* sugar foods and *two* starch foods [2]. Name *two* substances used to fix color in the process of dyeing cloth [2].

THE UNIVERSITY OF THE STATE OF NEW YORK

215th High School Examination

CHEMISTRY

Thursday, June 22, 1916—9.15 a.m. to 12.15 p.m., only

Write at top of first page of answer paper *a*) name of school where you have studied, *b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Describe the preparation and collection of dry hydrogen chloride in the laboratory [4]. Give *two* reasons for the method of collection [2]. Write the equation for the reaction [2]. Compare the properties of dry hydrogen chloride with those of hydrochloric acid [2].
2. Name a base that you have prepared in the laboratory [1]. Name the materials used [1]. Write the equation for the reaction [2]. Name *three* properties of bases [3]. Represent by an equation a reaction depending on one of these properties [3].
3. Five bottles are known to contain the following white powders:—sodium chloride, ammonium nitrate, calcium carbonate, silver sulfate, potassium bromide; how would you distinguish each? [10]

Group II

Answer at least one question from this group.

4. Two of the oxides of sulfur contain by weight respectively two parts of sulfur to two parts of oxygen and two parts of sulfur to three parts of oxygen; show how the composition of these compounds illustrates the law of *a*) definite proportions [4], *b*) multiple proportions [6].
5. State what is meant by *each* of the following:—destructive distillation, reduction, precipitation, normal salt, decrepitation. [10]
6. Mention important chemical and physical properties that make high explosives so destructively efficient in modern warfare [4]. What physical property of chlorine makes it so death-dealing in the trenches [2]? Mention *three* metals commonly used in coating iron implements to prevent rusting [3]. What country has been the chief source of platinum [1]?

Group III

Answer at least one question from this group.

7. Find the number of liters of ammonia gas that may be prepared from 107 grams of ammonium chloride and sufficient slaked lime. [10] (Atomic weights:—N = 14, Cl = 35.5.)
8. If a sample of gasoline is half hexane, C_6H_{14}, and half heptane, C_7H_{16}, how many cubic feet of air will be necessary for the complete combustion of 100 cubic feet of gasoline vapor? [10] (Assume air as one fifth oxygen by volume.)
9. Write the equation for the reaction of *a*) silver nitrate and ferric chloride, *b*) copper sulfate and barium chloride, *c*) baking soda and cream of tartar, *d*) silver and dilute nitric acid, *e*) potassium chloride, manganese dioxide and sulfuric acid. [10]

Group IV

Answer at least one question from either this group or group V.

10. Describe the electrolytic process of extracting aluminum [7]. In what common acid is aluminum easily soluble [1]? Why are solutions of strong alkalis unsuitable for cleaning aluminum cooking utensils [2]?
11. What is glass [3]? How is it made [3]? Name *two* materials used that affect the hardness of glass [2]. Why is glass annealed [1]? What is so-called water glass [1]?
12. Describe the process of smelting iron ore [3]. Compare the composition and the properties of cast iron with those of wrought iron [3]. Describe the crucible process of making steel and name some of the uses of crucible steel [4].

Group V

Answer at least one question from either this group or group IV.

13. Mention *two* articles of food that tarnish silver [2]. Give reason [2]. Name *two* products of coal tar that are used in *a*) the household [2], *b*) the industries [2]. What effect has the European war had on the cost of coal tar products [1]? Why [1]?
14. Mention *two* ways to keep milk from souring [2]. Which is used with sour milk for cooking, baking powder or baking soda [2]? Why [2]? Should baking powder be mixed with flour before or after adding liquid [2] Why [2]?

THE UNIVERSITY OF THE STATE OF NEW YORK

216th High School Examination

CHEMISTRY

Thursday, January 25, 1917—9.15 a.m. to 12.15 p.m., only

Write at top of first page of answer paper *a*) name of school where you have studied, *b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Make a diagram of the apparatus used in the laboratory for the preparation of bromine [2]. Write the equation for the reaction that takes place [2]. Name the chemical materials used [2] and give a reason for the use of each [2]. Mention *two* physical properties of bromine [2].
2. Classify *each* of the following substances and give *two* properties of each by which they are classified:—caustic soda, oil of vitriol, hydrogen sulfide, sodium hydrogen sulfate, potassium permanganate. [10]
3. Given the following pulverized substances how could you distinguish *a*) potassium chlorate from potassium chloride [2], *b*) sodium sulfate from sodium sulfide [2], *c*) washing soda from baking soda [2]? Describe the laboratory method of determining the per cent of water of crystallization in barium chloride [4].

Group II

Answer at least one question from this group.

4. Distinguish between *a*) chemical compound and mechanical mixture [2], *b*) solution and suspension [2], *c*) distillation and filtration [2], *d*) saturation and supersaturation [2], *e*) atom and ion [2].
5. Explain how molecular weight is related to vapor density [5]. State the theory accounting for this relation [5].
6. Show why the heat of neutralization of any base with any acid is a constant [4]. What is the law of the conservation of matter [4]? Illustrate this law [2].

Group III

Answer at least one question from this group.

7. What will a liter of oxygen weigh at 740 m.m. pressure and 20 ° C. if it weighs 1.43 grams under standard conditions? [10]
8. Find the cost of making 100 liters of hydrogen sulfide, given the following data (wholesale prices) :— sulfur 3¢ a kilogram, scrap iron 15¢ a kilogram, concentrated (assume 100%) sulfuric acid 2¢ a kilogram. [10] (Atomic weights:—S = 32, Fe = 55.5.)
9. How many liters of carbon dioxide will result from the complete combustion of 10 liters of carbon monoxide [5]? Find the weight of copper precipitated from sulfate solution by 10 grams of iron [5]. (Atomic weights:—S = 32, Cu = 63.1.)

Group IV

Answer at least one question from either this group or group V.

10. Describe electrolytic extraction of aluminum from bauxite [4]. What physical property is secured by alloying gold or silver with copper for ornaments [1]? Why is copper used for electric wiring [1]? Compare copper with lead as to physical properties and chemical activity [4].

11. Describe the manufacture of cast iron from hematite [4]. Distinguish between flux and slag [2]? How does cast iron differ from steel [2]? How is steel tempered [2]?
12. Compare gypsum with plaster of Paris as to composition and use [5]. What is the chemical composition of marble [1]? Mention *two* important uses of marble and designate the properties that fit it for these uses [4].

Group V

Answer at least one question from either this group or group IV.

13. Explain the action, in removing grease spots, of *a*) ammonia water [2], *b*) soap [2]. Explain why soap does not easily form suds with hard water [3]. Explain the action of hydrogen peroxide as a disinfectant [3].
14. Why is carbon dioxide a good fire extinguisher [2]? Why are metal containers used for the oily cotton waste in shops [2]? Name *one* acid, *one* base and *four* salts used in the home [6].

THE UNIVERSITY OF THE STATE OF NEW YORK

217th High School Examination

CHEMISTRY

Thursday, June 21, 1917—9.15 a.m. to 12.15 p.m., only

Write at top of first page of answer paper *a*) name of school where you have studied, *b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Describe the preparation and collection of iodine, using a labeled diagram of the apparatus employed [4]. Name the materials used and write the equation [3]. Mention an important source of iodine [1]. Mention *two* uses of iodine [2].
2. Describe with the aid of a diagram the method you used for the preparation and collection of sulfur dioxide by the action of acid on a metal [5]. Name the materials used and write the equation [5].
3. Give a test for *a*) a ferrous salt [2], *b*) a ferric salt [2]. How may a ferric salt be changed to a ferrous salt [3]? How may a ferrous salt be changed to a ferric salt [3]?

Group II

Answer at least one question from this group.

4. What is the difference between electrolytes and non-electrolytes [2]? Name *a*) two electrolytes [2], *b*) two non-electrolytes [2]. In terms of ions define *a*) acid [2], *b*) base [2].
5. Define and explain or illustrate what is meant by *a*) atomic hypothesis [2], *b*) Avogadro's hypothesis [2], *c*) catalytic agent [2], *d*) valence [2]. What is the relation of vapor density to molecular weight [2]?
6. State the valence of *a*) the first mentioned element in HgCl, BaO, Na_2SO_4, $Bi(OH)_3$, SO_3 [5], *b*) the acid radical in Na_4SiO_4, H_3BO_3, $Ca_3(PO_4)_2$, $AgNO_3$ Na_2CO_3 [5].

Group III

Answer at least one question from this group.

7. Write the equation to show the reaction between *a*) ferric chloride and silver nitrate in water solution [2], *b*) copper sulfate and hydrogen sulfide in water solution [2], *c*) sulfuric acid and dry sodium nitrate [2], *d*) ferrous sulfide and hydrochloric acid [2], *e*) ammonium hydroxide and nitric acid [2].
8. There are five molecules of water in each molecule of crystallized copper sulfate; find the number of grams of water required to crystallize 100 grams of anhydrous copper sulfate. [10] (Atomic weights: O = 16, S = 32, Cu = 63.6.)
9. How many liters of carbon dioxide gas will be formed by the fermentation of 180 grams of grape sugar according to the following equation: $C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$? [10] [Atomic weights: O = 16, C = 12].

Group IV

Answer at least one question from either this group or group V.

10. Give the essential features of the open hearth process of making steel [4]. Explain the chemistry of the

thermite process for welding steel [4]. What is so-called galvanized iron [2]?

11. How is sulfur extracted in Louisiana [3]? Name the man who worked out this process [2]. Name *two* allotropic forms of sulfur [2]. How is sulfur used in bleaching [3]?
12. Using a labeled diagram, describe the electrolytic process of preparing sodium hydroxide on a commercial scale from sodium chloride. [10]

Group V

Answer at least one question from either this group or group IV.

13. Mention *two* important sources of starch [2]. How is glucose made from starch [3]? What is meant by the inversion of sugar [3]? What are the products of the inversion of sugar [2]?
14. Explain the method of getting gasoline from crude petroleum [4]. Name *three* by-products of the process [3]. Explain the destructive distillation of wood on a commercial scale and name *three* products formed [3].
15. Compare ethyl alcohol with acetic acid as to *a*) formula [1], *b*) properties [2], *c*) uses [2]. Explain how acetic acid may be obtained from alcohol [3]. Write the equation [2].

THE UNIVERSITY OF THE STATE OF NEW YORK

218th High School Examination

CHEMISTRY

Thursday, January 24, 1918—9.15 a.m. to 12.15 p.m. only

Write at top of first page of answer paper *a*) name of school where you have studied, *b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Make a labeled diagram of the apparatus used in the laboratory for the preparation and collection of nitric acid [4]. Name the materials used and write the equation [2]. Mention *two* chemical properties of nitric acid [2]. Mention *two* uses of nitric acid [2].
2. Make a labeled diagram of the apparatus used in the laboratory for the preparation and collection of chlorine [2]. Name the materials used and write the equation [2]. Mention two chemical and two physical properties of chlorine [4]. Mention two important uses of chlorine [2].
3. How are flame tests made [3]? Give flame tests for salts of each of four different metals, mentioning the salts [4]. Explain the use of cobalt glass in making flame tests [3].

Group II

Answer at least one question from this group.

4. Distinguish between fusion and solution [2]. Define water of crystallization [2]. Name a salt that contains water of crystallization and state how you would determine the amount of water of crystallization it contains [4]. Distinguish between effervescence and efflorescence [2].
5. Define and illustrate *a*) symbol [2], *b*) formula [2], *c*) chemical equation [2], *d*) acid [2], *e*) double salt [2].
6. Explain how mercuric oxide and potassium iodide illustrate the law of definite proportions [4]. Explain how carbon monoxide and carbon dioxide illustrate the law of multiple proportions [2]. State these laws [4].

Group III

Answer at least one question from this group.

7. Write the equation showing the reaction between *a*) ferrous sulfide and hydrochloric acid [2], *b*) copper and dilute nitric acid [2], *c*) aluminum and sodium hydroxide [2], *d*) water solutions of potassium chloride and sodium nitrate [2], *e*) water solutions of silver nitrate and barium chloride [2].
8. Find the number of liters of oxygen gas measured under standard conditions produced by the decomposition of 245 grams of potassium chlorate. [10] (Atomic weights:—K = 39, Cl = 35.5, O = 16.)
9. What will a liter of carbon dioxide weigh at 750 m.m. pressure and 20° C. temperature, if it weighs 1.98 grams at 776 m.m. pressure and 0° C. temperature? [10]

Group IV

Answer at least one question from either this group or group V.

10. Describe the manufacture of sulfuric acid on a commercial scale by the contact process [6]. Mention *two*

industries that require large quantities of sulfuric acid and explain how it is used in *each* of the industries mentioned [4].

11. Describe the manufacture of cast iron and wrought iron [5]. How does wrought iron differ from steel [2]? Describe *three* methods of protecting iron from corrosion [3].
12. Mention *two* important ores of zinc [2]. Describe the process of extracting zinc from *one* of the ores mentioned [5]. What use of zinc is of immense importance to the United States Government at the present time [3]?

Group V

Answer at least one question from either this group or group IV.

13. Describe *two* processes by which the fixation of atmospheric nitrogen is accomplished [4]. Explain the importance of the fixation of atmospheric nitrogen in times of peace as well as for the prosecution of the present war [6].
14. Mention the raw material, describing the method of manufacture from that material, of *a*) methyl alcohol [2], *b*) ethyl alcohol [2]. Mention *two* important commercial uses of ethyl alcohol [2]. What is denatured alcohol [2]? What is the object of denaturing alcohol [2]?
15. Give the chemical test by which one may *a*) determine whether a fabric is all wool or has some cotton in its texture [5], *b)* distinguish natural silk from artificial silk [5].

THE UNIVERSITY OF THE STATE OF NEW YORK

219th High School Examination

CHEMISTRY

Thursday, June 20, 1918—9.15 a.m. to 12.15 p.m., only

Write at top of first page of answer paper (*a*) name of school where you have studied, (*b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Mention *three* laboratory ways of collecting gases, naming a gas in each case [3]. State and explain the proper adjustments to be made to a Bunsen burner or a gas range that strikes back [3]. State, with reasons, whether it is safe to bring a flame near *a*) an oxygen generator [2], *b*) a hydrogen generator [2].
2. Distinguish between *a*) supporter of combustion and combustible substance [2], *b*) acid salt and normal salt [2], *c*) the meanings of the suffixes "ic" and "ous," giving *two* formulas to illustrate each [6].
3. Describe with the aid of a labeled diagram the laboratory preparation and collection of iodine [4]. Write the equation [2]. Mention properties of iodine on which its tincture depends as to *a*) preparation [2], *b*) uses [2].

Group II

Answer at least one question from this group.

4. What is fixation of nitrogen [2]? Mention *two* chief commercial sources of combined nitrogen [2]. Describe a commercial method and a natural process by which nitrogen is fixed [4]. Give *two* important reasons why a country must be well supplied with combined nitrogen [2].
5. Make a labeled diagram of the apparatus for commercial electrolysis of brine and state the importance of this process [4]. Explain in terms of ions the action on litmus of a water solution of *a*) HCl [2], *b*) NaOH [2], *c*) NaCl [2].
6. State the law of multiple proportions [4]. Illustrate by the union of sulfur and oxygen forming *two* compounds, giving name and percentage composition by weight of each [6]. (Atomic weights:—S = 32, O = 16.)

Group III

Answer at least one question from this group.

7. Name a gas composed of two elements, which, when burned in air or oxygen, forms water and sulfur dioxide [3]. How many liters of oxygen are required for the complete combustion of five liters of this gas [7]?
8. Find the weight and the volumes of oxygen and hydrogen forming 180 grams of water. [10] (Atomic weight:—O = 16.)
9. Find the weight of ammonium sulfate necessary, when heated with the required amount of slaked lime, to make two liters of ammonia water, allowing 700 volumes of ammonia gas to one volume of water for full strength solution. [10] (Atomic weights:—S = 32, N = 14.)

Group IV

Answer at least one question from either this group or group V.

10. Describe with the aid of labeled diagrams of the furnaces a commercial method for converting iron ore containing sand into steel. [10]
11. Mention the ingredients of a rock necessary to make *a*) good cement [1], *b*) lime [1]. Describe a commercial process for the manufacture of lime and write the equation for the essential reaction [4]. Compare the hardening of a cement mortar with that of a lime mortar [4].
12. Describe, giving equations, the contact process of making sulfuric acid [4]. Give an example of its use *a*) in the laboratory for oxidizing [2], *b*) commercially for dehydrating [2], *c*) in making a fertilizer [2].

Group V

Answer at least one question from either this group or group IV.

13. Tell concerning potash *a*) what it is [2], *b*) its commercial sources [3], *c*) its important uses [3]. Explain the marked shortage of potash in the United States at the present time [2].
14. Give a practical method of detecting the presence and determining the amount of cotton in mixed cotton and woolen goods [3]. What bleaching agent should be used for *a*) cotton [2], *b*) wool [2]? Explain the action of each agent [3].
15. Give in tabular form the name, chief commercial source, composition (formula not required) and an important use in the home of *one* example selected from *each* of the following: hydrocarbons, alcohols, organic acids, esters, carbohydrates. [10]

THE UNIVERSITY OF THE STATE OF NEW YORK

220th High School Examination

CHEMISTRY

Thursday, January 23, 1919—9.15 a.m to 12.15 p.m., only

Write at top of first page of answer paper (*a*) name of school where you have studied, (*b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions.

Group I

1. Describe the best procedure in cutting, bending and annealing glass tubing [6]. Describe *two* laboratory methods of separating a solid solute from a liquid solvent [4].
2. Describe, using a labeled diagram, a laboratory method of preparing concentrated hydrochloric acid and write the equation [5]. Give *three* reasons for the use in this reaction of the acid designated in the first member of the equation [3]. Describe *two* methods of identifying concentrated hydrochloric acid found in an unlabeled bottle [2].
3. Define combustion [2]. Describe an experiment that clearly shows why, through not using a chemical balance, the early investigators failed to find the present explanation of ordinary burning [6]. Give the name and the nationality of the chemist who by the use of the balance first gave the present explanation of burning [2].

Group II

4. Give the laboratory procedure for *a*) preparing washing soda crystals from the dry powder [3], *b*) preparing pure sodium chloride from common salt [3], *c*) separating potassium nitrate and sodium chloride from a mixture of the two [3]. Mention a way of forming salts [1].
5. State the properties common to all acids [3]. Give the name of an acid commonly used by *a*) tinsmiths [1], *b*) silversmiths [1], *c*) goldsmiths [1], *d*) in refining petroleum [1]. State the properties common to all bases [3].
6. Make a labeled diagram of the apparatus for the electrolysis of water, showing *a*) by arrows the direction of the current [3], *b*) anode and cathode [3], *c*) relative volume and name of gas liberated at each electrode [4].

Group III

7. Find the number of grams of copper needed to prepare 10 liters of nitric oxide by interaction with moderately dilute nitric acid. [10] (Atomic weights:—O = 16, Cu = 63.6, N = 14.)
8. Find the per cent of copper in bluestone, $CuSO_4 . 5H_2O$. [10] (Atomic weights:—O = 16, Cu = 63.6, S = 32.)
9. If 5 grams of hydrated barium chloride, heated to constant weight, weigh 4.265 grams, find *a*) the per cent of water in the crystals [5], *b*) the number of molecules of water of crystallization per molecule of barium chloride [5]. (Atomic weights:—O = 16, Ba = 137, Cl = 35.5.)

Group IV

10. Name *a*) *one* metal that is reduced from its ore by carbon [2], *b*) one prepared by electrolysis [2], *c*) *two* occurring extensively in the free state [2]. Name an

alloy of each of these metals and the constituents of each alloy [4].

11. Write the name, formula and color of the nonvolatile product formed by heating in an oxidizing flame *each* of the following: aluminum sulfate, granulated zinc, magnesium ribbon [7]. What is the color of each residue when these products are separately ignited with cobalt nitrate [3]?
12. What properties fit carbon dioxide for use in *a*) beverages [2], *b*) fire extinguishers [2]? Why can almost any acid be used in preparing carbon dioxide [2]? Describe the chemical test for carbon dioxide and tell how to show that the gas is a product of ordinary burning [4].

Group V

13. Give the materials necessary for fermentation of glucose and state the conditions favorable to this fermentation [3]. Name the principal products formed and give a test for each [4]. Describe an experiment to show how one of these products is commercially recovered [3].
14. To what class of organic compounds does *each* of the following belong: glycerin, cotton [2]? In connection with *each* of the foregoing, name a concentrated acid with which it is treated and an important commercial product thus formed [4]. Explain the use of carbon derived from peach pits in making gas masks [2]. To which of the allotropic forms of carbon does it belong [2]?
15. How is soap made [4]? Explain its use [6].

THE UNIVERSITY OF THE STATE OF NEW YORK

221st High School Examination

CHEMISTRY

Thursday, June, 19, 1919—9.15 a.m. to 12.15 p.m., only

Write at top of first page of answer paper (*a*) name of school where you have studied, (*b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Describe an experiment to determine *a*) whether a physical or a chemical change takes place when a metal, such as copper or magnesium, is heated in air [3], *b*) whether decomposition or combination takes place during the heating of the metal [3], *c*) the name of the nonmetallic substance taking part in the change [4].
2. Make a sectional drawing of the apparatus used in the laboratory for the preparation and collection of hydrogen sulfide [3]. Write the equation for the reaction [2]. State *three* physical properties of hydrogen sulfide [3]. For what purpose does the chemist use hydrogen sulfide [2]?
3. With the aid of drawings describe the preparation, separation and collection of alcohol [3]. State conditions essential to the preparation of alcohol [3]. Write the equation for the preparation of alcohol from one compound [2]. Mention *two* industrial uses of alcohol [2].

Group II

Answer at least one question from this group.

4. Define and illustrate each of *five* of the following terms: water of crystallization, neutralization, destructive distillation, allotropic forms, heat of formation, catalysis, solute. [10]
5. Show why the molecular weight of a gaseous compound is twice its vapor density. [10]
6. According to the hypothesis of electrolytic dissociation, what takes place when *a*) an electrolyte dissolves in water [3], *b*) a nonelectrolyte dissolves in water [3], *c*) a direct current of electricity passes through a water solution of hydrogen chloride [4]?

Group III

Answer at least one question from this group.

7. What weight of ammonia could be obtained (theoretically) by heating 100 pounds of ammonium sulfate with an excess of slaked lime [7]? What volume would it occupy [3]? (Atomic weights:—N = 14, S = 32, O = 16. 1 cu. ft. of ammonia weighs .048 lb.)
8. What volume of oxygen would be required for the complete combustion of 1000 cubic feet of acetylene? [10]
9. A certain gas consists of 14.29% of hydrogen in combination with 85.71% of carbon. Measured at standard conditions 50 cubic centimeters of the gas weighs .063 grams. Calculate the chemical formula of the gas. [10] (Atomic weight:—C = 12.)

Group IV

Answer at least one question from either this group or group V.

10. Write a chemical equation for *a*) the manufacture of quicklime from limestone [2], *b*) the slaking of lime [2], *c*) the manufacture of nitric acid [2], *d*) the acetic acid fermentation of alcohol [2], *e*) the manufacture of glucose from starch [2].

11. Draw a diagram of an open hearth furnace and describe the manufacture of open hearth steel [6]. How does steel differ in composition and properties from *a*) cast iron [2], *b*) wrought iron [2]?
12. Describe the manufacture of *a*) enriched water gas [5], *b*) producer gas [5].

Group V

Answer at least one question from either this group or group IV.

13. Mention *two* important industrial uses in times of peace of *a*) chlorine [2], *b*) sulfuric acid [2], *c*) nitric acid [2], *d*) tin [2], *e*) monocalcium phosphate [2].
14. Describe *two* methods employed in cookery for the production of carbon dioxide [4]. Why is carbon dioxide given off when temporary hard water is boiled [3]? Why is sodium bicarbonate instead of sodium carbonate used in chemical fire extinguishers [3]?
15. What chemical test would you employ to distinguish between *a*) sodium nitrate and potassium nitrate [2], *b*) copper chloride and copper nitrate [2], *c*) ferrous sulfate and ferric sulfate [2], *d*) limestone and gypsum [2], *e*) ammonium acetate and magnesium bromide [2]?

THE UNIVERSITY OF THE STATE OF NEW YORK

222d High School Examination

CHEMISTRY

Thursday, January, 22, 1920—9.15 a.m. to 12.15 p.m., only

Write at top of first page of answer paper (*a*) name of school where you have studied, (*b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Describe *three* methods of making hydrogen [3]. Write *three* chemical equations, one to illustrate each method described [3]. Mention an important physical property, an important chemical property and *two* uses of hydrogen, one dependent on each property mentioned [4].
2. Make a drawing of the apparatus for the laboratory preparation and collection of sulfur dioxide [3]. Write the equation to represent the reaction [3]. Sulfur dioxide is the anhydride of what acid [1]? How is sulfur dioxide converted into the anhydride of sulfuric acid [1]? How may a sulfite be distinguished from a sulfate [2]?
3. How would you identify by chemical tests *each* compound if given samples of the five following compounds: aluminum sulfate, ferrous sulfate, ferric sulfate, ammonium sulfate, zinc sulfate? [10]

Group II

Answer at least one question from this group.

4. Give reasons for the belief that the chlorine molecule contains two atoms. [10]
5. Define and illustrate *each* of the following: dissociation, destructive distillation, fractional distillation, electrolysis, saturated solution. [10]
6. Why does the reaction go to completion when *a*) a solution of silver nitrate is added to a solution of sodium chloride [2], *b*) hydrochloric acid is added to marble [2], *c*) chlorine water is added to a solution of potassium iodide [2], *d*) nitric acid is neutralized with potassium hydroxide [2], *e*) limestone is heated to a high temperature in air [2]?

Group III

Answer at least one question from this group.

7. A gas is found by analysis to contain 46.15% of carbon and 53.85% of nitrogen; 57 c.c. of this gas, reduced to standard conditions, weighs .1334 grams. From the above data derive the chemical formula of the gas. [10] (Atomic weights:—C = 12, N = 14.)
8. What weight of iron could be obtained theoretically from 200 tons of ore containing 85% ferric oxide? [10] (Atomic weights:—Fe = 56, O = 16.)
9. Write chemical equations to represent the following reactions: *a*) iron placed in a solution of copper sulfate [2], *b*) magnesium carbonate with citric acid [2], *c*) aluminum with hydrochloric acid [2], *d*) water solutions of sodium acid carbonate and calcium hydroxide [2], *e*) silver with cold dilute nitric acid [2].

Group IV

Answer at least one question from either this group or group V.

10. How may zinc be obtained from an ore consisting chiefly of zinc sulfide [4]? Mention *three* important

properties of zinc and *three* uses, one dependent on each property mentioned [6].

11. Describe the manufacture of plaster of Paris [5]. Why is plaster of Paris suitable for use in making casts [1]? Is water containing calcium sulfate in solution a soft water, a temporary hard water or a permanent hard water [1]? Give reasons for your last answer [3].
12. How is coke manufactured [4]? Name *three* valuable by-products that should be recovered during the manufacture of coke [3]. Mention *three* industrial uses of coke [3].

Group V

Answer at least one question from either this group or group IV.

13. Name *five* substances used as protective coatings on iron and state the commercial name of the iron with its protective coating, in cases where such name is in common use [5]. Which, if any, of the coatings mentioned would be unsuitable for use on cooking utensils [2]? Why [3]?
14. Why is the fixation of nitrogen of importance to the United States in *a*) time of war [2], *b*) time of peace [2]? Describe a method employed for the manufacture of nitric acid from the nitrogen of the atmosphere [6].
15. Describe the manufacture of hard soap [5]. What class of carbon compounds includes fats suitable for soap making [1]? What alcohol is a by-product of soap making [1]? Name an explosive made from this alcohol with nitric acid and account for its power [3].

THE UNIVERSITY OF THE STATE OF NEW YORK

223d High School Examination

CHEMISTRY

Thursday, June 17, 1920—9.15 a.m. to 12.15 p.m., only

Write at top of first page of answer paper (*a*) name of school where you have studied, (*b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Make a drawing of the apparatus used and describe a laboratory method for the preparation of chlorine [3]. Write the equation to represent the reaction [3]. What are the physical properties of chlorine [3]? Name an element with which chlorine readily combines [1].
2. Select an element that has the property of allotropism and tell how *two* modifications of the element can be prepared [8]. Which of the allotropic forms is the more stable at ordinary conditions [2]?
3. Give a chemical test for *a*) a soluble chloride [2], *b*) a nitrate [2], *c*) a carbonate [2], *d*) an iodide [2], *e*) an acetate [2].

Group II

Answer at least one question from this group.

4. Define *each* of the following terms: *a*) water of crystallization [2], *b*) supersaturation [2], *c*) Avogadro's law [2], *d*) heat of formation [2], *e*) hydrolysis [2].
5. Why is a gram-molecule of a gas the weight of 22.4 liters? [10]
6. Using chemical formulas, write the following equations in complete form: [10]
   - *a* zinc + hydrochloric acid =
   - *b* calcium carbonate + nitric acid =
   - *c* sodium sulfate + barium chloride =
   - *d* silver + nitric acid =
   - *e* aluminum sulfate + calcium hydroxide =

Group III

Answer at least one question from this group.

7. What weight of sodium chloride will precipitate all of the silver from a solution made by dissolving 1 gram of silver in nitric acid? [10] (Atomic weights:— Na = 23, Cl = 35.5, Ag = 108, N = 14, O = 16.)
8. How many liters of hydrogen chloride at standard conditions will be necessary to neutralize a water solution of 10 grams of sodium hydroxide? [10] (Atomic weights: Cl = 35.5, Na = 23, O = 16.)
9. Assuming air to contain 20 per cent. of oxygen, state how many cubic feet of air would be required for the complete combustion of 1000 cubic feet of acetylene. [10]

Group IV

Answer at least one question from either this group or group V

10. Name a raw material from which *each* of the following is manufactured: quicklime, steel, superphosphate of lime, plaster of Paris, aluminum, illuminating gas, gasoline, nitric acid charcoal, washing soda. [10]
11. With the aid of a drawing describe the manufacture

of steel by the "open hearth" process [6]. What changes does this process bring about [4]?

12. Briefly describe the manufacture of *a*) calcium carbide [3], *b*) carborundum [3]. Mention *two* important uses of calcium carbide [2]. Write the formula and mention the chief use of carborundum [2].

Group V

Answer at least one question from either this group or group IV.

13. Define "carbohydrate" [3]. How is dextrose (glucose) prepared on a commercial scale [5]? Mention *two* important uses of glucose [2].
14. What is the common name of *a*) crude methyl alcohol [1], *b*) ethyl alcohol [1]? State *three* important uses of methyl alcohol [3]. Show how danger may arise from ignorance concerning the properties of methyl alcohol [4]. What is denatured alcohol [1]?
15. Briefly describe and represent by chemical equations the two principal changes that take place when vinegar is obtained from sweet cider. [10]

THE UNIVERSITY OF THE STATE OF NEW YORK

224th High School Examination

CHEMISTRY

Thursday, January 20, 1921—9.15 a.m to 12.15 p.m., only

Write at top of first page of answer paper (*a*) name of school where you have studied, (*b*) number of weeks and recitations a week in chemistry, with the total number of laboratory periods and the length of such periods.

The minimum time requirement is five recitations a week for a school year. A double laboratory period counts in place of one recitation. Laboratory work equivalent to 30 double periods is required.

Answer 10 questions, selecting at least one from each of the first three groups and at least one from either group IV or group V.

The teacher in charge of the examination may advise the class of candidates to select from group IV or to select from group V.

Group I

Answer at least one question from this group.

1. Make a diagram of the apparatus for preparing and collecting sulfur dioxide [3]. Write the equation [3]. Mention *two* important industrial uses of sulfur dioxide [2]. Of what acid is sulfur dioxide the anhydride [2]?
2. Give *two* chemical methods for distinguishing between hydrogen and carbon monoxide [2], oxygen and nitrous oxide [2], a sulfate and a chloride [2], a zinc compound and a cobalt compound [2], a nitrate and an acetate [2].
3. Describe the laboratory preparation of temporary hard water [2]. What chemical changes took place [2]? Write the equations [2]. Describe a commercial method of softening a temporary hard water [2]. Write the equation [2].

Group II

Answer at least one question from this group.

4. Using chemical formulas, write the following reactions in complete form:
   a Potassium chlorate (heated) = [2]
   b Sodium chloride + sulfuric acid = [2]
   c Aluminum sulfate + ammonium hydroxide = [2]
   d Copper + diluted nitric acid = [2]
   e Lead acetate + hydrogen sulfide = [2]
5. Using the theory of ionization in water solutions, explain why the reaction runs to completion when *a*) nitric acid is added to marble [3], *b*) sodium hydroxide is neutralized with hydrochloric acid [3]. Explain the alkaline reaction of a water solution of sodium carbonate [4].
6. State Avogadro's law [2]. Measured under like conditions, two volumes of hydrogen can be combined with one volume of oxygen to form two volumes of steam. Using this fact and Avogadro's law, show that a molecule of oxygen contains at least two atoms [8].

Group III

Answer at least one question from this group.

7. Calculate the weight of barium chloride which, reacting with sufficient sulfuric acid, yields 1.46 grams of barium sulfate. [10] (Atomic weights:—Ba = 137, Cl = 35.6, S = 32, O = 16.)
8. How many liters of chlorine (standard conditions) are required to liberate 40 grams of bromine from a solution of potassium bromide? [10] (Atomic weights:—Br = 80, K = 39, Cl = 35.6.)
9. Find the volume of methane whose complete combustion forms 10 cubic feet of carbon dioxide. [10] (Atomic weights:—C = 12, O = 16.)

Group IV

Answer at least one question from either this group or group V.

10. Describe a commercial process for the production of chlorine [3]. Give *a*) *three* physical and *two* chemical properties of chlorine [5], *b*) *two* industrial uses [2].
11. Make a labeled diagram of a blast furnace [3]. Describe the process of making cast iron from an ore consisting of hematite mixed with quartz [4]. State the reason for the use of each ingredient of the furnace charge [3].
12. Beginning with calcium carbonate, tell how to prepare *a*) quicklime [1], *b*) slaked lime [1], *c*) calcium chloride [1], *d*) carbonic anhydride [1]. Write the equations [4]. Mention an important use of each of *two* preparations [2].

Group V

Answer at least one question from either this group or group IV.

13. Are baking powders mixtures or compounds [1]? Why [1]? State the reason for storing baking powders in closed containers [2]. Should a baking powder be mixed with the flour before or after the addition of water [1]? Why [2]? Name *three* classes of baking powders [3].
14. How does an ester differ from a salt in *a*) preparation [2], *b*) composition [2], *c*) properties [2]? Give the formula and an important use of each of *two* esters [4].
15. Give the formula and an industrial use of *a*) a carbohydrate [2], *b*) a hydrocarbon [2], *c*) an alcohol [2]. Explain the expression "inversion of sugar" [4].

A TABLE OF THE MORE COMMON ELEMENTS

With Their Symbols and Approximate Atomic Weights

Element	*Symbol*	*Approx. At. Wt.*	*Element*	*Symbol*	*Approx. At. Wt.*
Aluminum	Al	27	Manganese	Mn	55
Barium	Ba	137	Mercury	Hg	200
Bromine	Br	80	Nickel	Ni	58.7
Calcium	Ca	40	Nitrogen	N	14
Carbon	C	12	Oxygen	O	16
Chlorine	Cr	52	Phosphorus	P	31
Chromium	Cl	35.5	Platinum	Pt	195
Copper	Cu	63.6	Potassium	K	39
Fluorine	F	19	Radium	Ra	226
Gold	Au	197	Silicon	Si	28
Helium	He	4	Silver	Ag	108
Hydrogen	H	1	Sodium	Na	23
Iodine	I	127	Sulfur	S	32
Iron	Fe	56	Tin	Sn	119
Lead	Pb	207	Tungsten	W	184
Magnesium	Mg	24	Zinc	Zn	65

APPROXIMATE WEIGHT OF 1 LITER OF COMMON GASES AT STANDARD CONDITIONS

Acetylene	1.16 grams	Hydrogen chloride	1.63 grams
Air	1.29 "	Hydrogen sulfide	1.52 "
Ammonia	0.77 "	Methane	0.72 "
Carbon dioxide	1.98 "	Nitric oxide	1.34 "
Carbon monoxide	1.25 "	Nitrogen	1.25 "
Chlorine	3.17 "	Nitrous oxide	1.98 "
Helium	0.18 "	Oxygen	1.43 "
Hydrogen	0.09 "	Sulfur dioxide	2.86 "

AQUEOUS VAPOR PRESSURE

(In millimeters of mercury)

Temperature	*Pressure*	*Temperature*	*Pressure*
0° C.	4.6 m.m.	23° C.	21.0 m.m.
1°	4.9	24°	22.3
2°	5.3	25°	23.7
3°	5.7	26°	25.1
4°	6.1	27°	26.7
5°	6.5	28°	28.3
6°	7.0	29°	29.9
7°	7.5	30°	31.7
8°	8.0	35°	41.6
9°	8.6	40°	54.9
10°	9.2	50°	92.3
11°	9.8	60°	148.9
12°	10.5	70°	233.3
13°	11.2	80°	354.9
14°	12.0	90°	525.5
15°	12.8	100°	760.0
16°	13.6		
17°	14.5		
18°	15.5		
19°	16.5		
20°	17.5		
21°	18.6		
22°	19.8		

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